WAR DEPARTMENT TECHNICAL MANUAL

TM 8-280

This manual supersedes TM 8-240, Roentgenographic Technicians, 3 July 1941, and TM 8-275, Military Roentgenology, 26 January 1942.

MILITARY ROENTGENOLOGY

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CHAPTER 1

INTRODUCTION

SECTION I. GENERAL

1. PURPOSE AND SCOPE. This manual is intended to serve a twofold purpose: first, as a general outline for a course of instruction of student x-ray technicians, and, second, as a reference text, particularly with respect to exposure factors and reminders of the gamut of precautionary measures which should lead toward the goal of perfection in the practice of roentgenography. In addition, it may serve to fix clearly in the mind of the technician the three phases of responsibility which must be recognized and mastered by him: first, he must be able to operate and maintain roentgen ray equipment with precision, safety and confidence; second, he must be able to visualize and understand the anatomy of the human body, and reproduce its shadows consistently and satisfactorily onto films; and third, he must be thoroughly acquainted with the operational programs of the department. Necessarily, the descriptions and explanations have been limited to fundamentals. Variations in designs and construction features of x-ray equipment are today so numerous that for these aspects it is necessary to refer to descriptive literature as issued by the manufacturers and to texts which deal essentially with x-ray physics.

SECTION II. SCIENCE OF ROENTGENOLOGY

2. HISTORY. Roentgen rays were discovered in 1895 by Wilhelm Conrad Roentgen. At first they were called x-rays; now, scientists refer to them as *roentgen rays*. Very early it was discovered that they possess the amazing power of penetrating solids and otherwise opaque media. This power of x-rays distinguishes them from practically all other types of radiation. Professor Roentgen passed the rays through wood, cloth and living tissues. Later, lead, iron and other heavy materials were shown to be transparent to them in varying degrees. Roentgen demonstrated their property of darkening photographic plates, and that they cause many substances to emit light. The latter action is called *fluorescence*. Photographic and fluorescent actions, together with their great penetrating power form the basis for their application to roentgen-ray techniques.

3. THE PRODUCTION OF ROENTGEN RAYS. a. General. Electricity is a flow of negatively charged particles called *electrons*. This flow normally occurs along wire conductors. If the speed of travel of the electrons is high, they will hop across a gap in the wire conductor. When electrons *rapidly moving* across such a gap are *suddenly stopped* by hitting a metal target, which has been placed in their path, roentgen rays (x-rays) are produced. The following comparison may lead to a clearer understanding of roentgen-ray production. If one throws a handful of marbles at a drumhead, the marbles striking the drum lose their velocity but cause the drumhead to vibrate. This vibration results in sending out waves in the air called sound. The marbles represent the electrons, the force with which they are set in motion corresponds to the high tension electric current which sets them in motion; the drumhead corresponds to the target of the x-ray tube and the resulting sound waves in the air correspond to the roentgen rays (x-rays) which are produced in the tube.

b. Roentgen ray machine. The roentgen ray machine provides three necessary elements (fig. 1):

(1) A source of electrons,

(2) A means of producing and controlling their high speed motion,

(3) A means of slowing them down and stopping them.

These elements are provided by the combined operation of three main parts of the x-ray machine: The x-ray tube, the transformer and the control.

c. X-ray tube. The electron source, or corpuscular ray requirements of the modern x-ray machine is the hot filament of the x-ray tube. The tungsten filament (heated to incandescence) emits electrons. At room temperature these electrons are bound to atoms of the metal that the filament is made of. When the filament is heated, many of these electrons

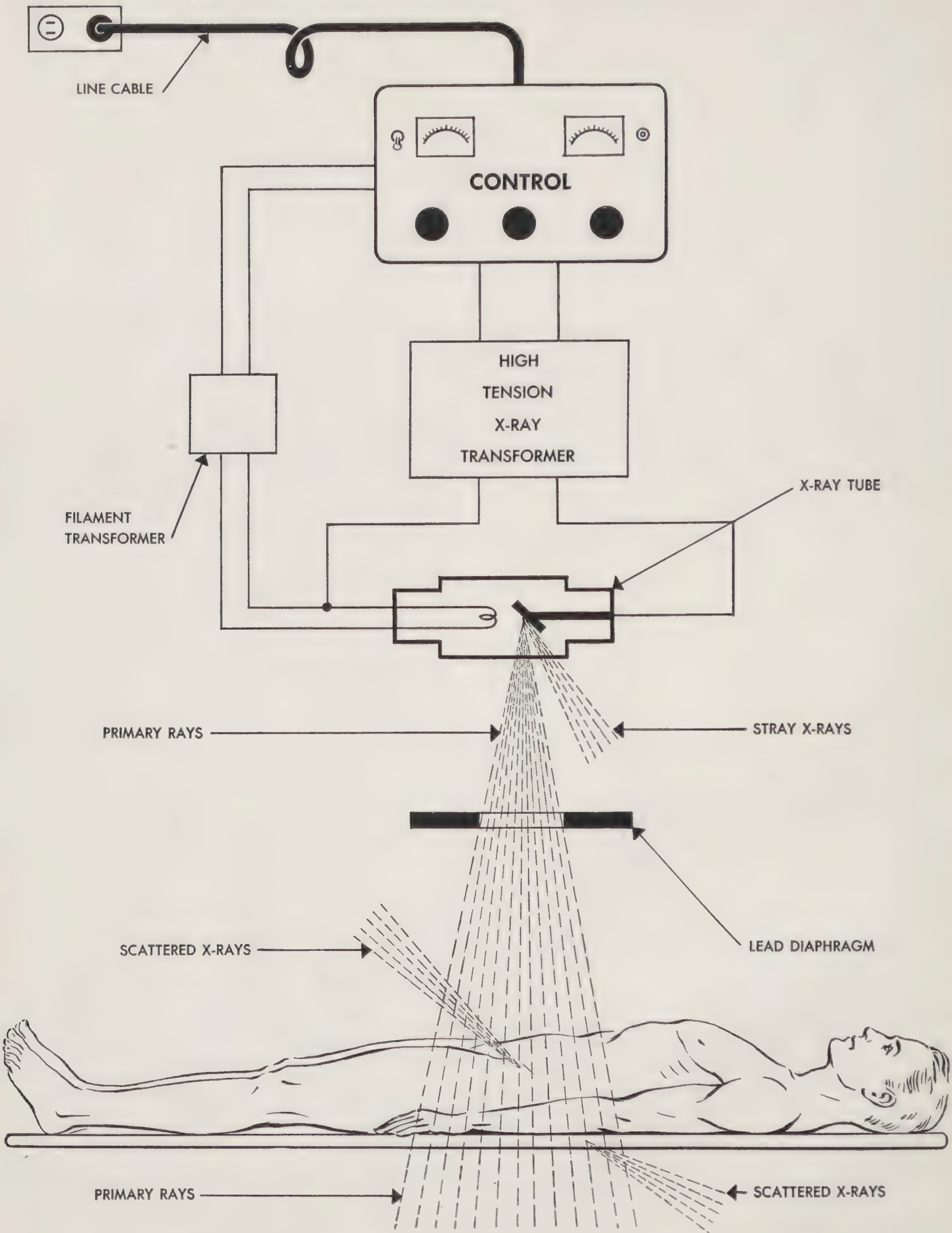


Figure 1. Schematic application of the roentgen-ray machine.

are momentarily set free. Since the electrons are negative particles they will be attracted to any strongly charged positive element in the tube. This element is the target which serves the double purpose of attracting the electrons to it at high speed and then suddenly stopping them by collision. High voltage electric current drives the negative electrons into collision with the positively charged target. The higher the voltage (that is, the greater the electromotive force) the faster the electrons will travel, and the greater will be the impact on the target.

d. Transformers. The high voltage electricity is produced by "stepping-up" the usual electric current supply of 110 to 220 volts to a potential of about 50,000 volts. The apparatus which produces this higher voltage current is the step-up transformer. In some machines this transformer and the x-ray tube are built as an integral unit, while in others the transformer is separate and connected to the tube by special high tension cables. In addition the x-ray apparatus contains a step-down transformer which supplies a low voltage current (3–10 volts, 3–5 amperes) to heat the filament of the x-ray tube. The greater the heating, the more freely are the electrons released for bombardment of the target.

e. Control. As the name suggests the control is the central location for connection and coordination of the various circuits. It contains the operating switches, circuit breakers, voltage and amperage indicators, and controls for varying the filament current.

4. MEDICAL APPLICATIONS. a. Roentgen rays serve two purposes in the practice of medicine: diagnosis and treatment of certain diseases. The first of these applications is identified as *roentgen diagnosis;* the second, *roentgen therapy.* Roentgen diagnosis and therapy, together, are covered by the field of *roentgenology.* Physician specialists who practice roentgenology are called *roentgenologists.*

b. Because roentgen rays cause changes in the activities of living tissue, only a limited portion of the patient's body should be exposed to the rays (fig. 1) in roentgen diagnosis or therapy.

c. With any such exposures many of the rays are stopped or absorbed, by the tissues, while some pass entirely through. The *absorbed rays* are responsible for the therapeutic effects in diseased tissues. Roentgen therapy is, therefore, primarily concerned with them.

d. Those rays which penetrate the tissues may be used to sensitize a photographic emulsion and thereby produce a permanent record or they may be utilized to activate a fluorescent substance, producing a momentary image, on fluoroscopic screens. The various intensities of the shadow images on the films or screens depend upon the characteristics of the tissues through which the rays have passed. The procedure of recording roentgen rays shadows on films is called *roentgenography*, and the finished record is identified as a *roentgenogram.* When the shadow images are displayed on a fluoroscopic screen, the procedure is called *roentgenoscopy;* that is, fluoroscopy.

CHAPTER 2

FUNDAMENTALS OF ROENTGENOLOGIC PHYSICS

SECTION I. BASIC PRINCIPLES

5. GENERAL. In order to clearly understand the practical application of roentgen-ray energy it is important that there be developed some knowledge as to the fundamentals concerned with roentgen rays; their nature, characteristics, means of development, and the electrical principle of the component parts of the generating equipment.

6. NATURE OF ROENTGEN RAYS. a. Roentgen rays are waves of radiant energy, similar in some respects to light. Roentgen rays and light move equally fast (186,000 miles per second). Both constitute portions of the same electromagnetic spectrum. (See fig. 2.)

b. The nature of roentgen rays is understood more readily if contrasted with other radiations. (See table I, app. V.) There are, in general, two distinct types of radiation: corpuscular and wavelike radiation. Corpuscular radiations are minute particles of matter. Although incredibly small, they possess mass. Some are charged electrically; all move extremely fast; in fact, almost as fast as light. Examples of corpuscular radiations are cathode rays and the alpha or beta particles of radium.

c. Wavelike radiations are all classified under the name electromagnetic radiations. As waves of radiant energy they possess neither mass nor electrical charge. Radio-waves, light, ultraviolet rays, cosmic rays, and roentgen rays, all are examples.

d. The principal properties of roentgen rays are given in table II, app. V.

e. Roentgen rays are characterized by their *intensity* and by their *wavelength*. Intensity designates quantity of radiant energy, while wavelength describes quality. In general, short wavelengths are more penetrating than long wavelengths. This is true for roentgen rays, although it is not true for all electromagnetic waves.

f. The product of wavelength and frequency of electromagnetic radiations is equal to the speed of the rays; thus, $\lambda \times \nu = c$, where lambda (λ), nu (ν) and c are wavelength, frequency and speed, respectively. The practical unit of wavelength is the Angstrom. Its symbol is Å. One Å is equal to .00000001 centimeter (10^{-8} cm.) Roentgen ray wavelengths range from 5 Å to .08 Å. (See fig. 2.)

g. The fundamental unit of roentgen-ray energy is designated in quanta. One quantum is equal to the product of frequency and a constant, represented by the letter (h), called "Planck's constant." Thus, one quantum is $h \times \nu$. Since $\nu = c$, one quantum $= h \times c$. Planck's constant (h) is equal to 6.554×10^{-27}. Thus, quanta are measured in *ergs*, the fundamental unit of energy.

7. ELECTRICAL STRUCTURE OF MATTER. a. Matter might be defined as anything which occupies space and has weight. Matter may exist in three states: gaseous, liquid, and solid. Thus, for example, steam, water, and ice are the same matter but they exist in different forms. Any type of matter, existing in any form, might be subdivided until it has uniform *character* throughout. Such would be a break-down into "pure substance." If division upon division of any "pure substance" is made, finally, there will result a small particle, which still retains all the characteristics of the substance. This small particle is called a "molecule."

b. Molecules may be composed of single elements, or they may be composed of two or more elements. Thus, a molecule of hydrogen contains only the element hydrogen, while a molecule of water is composed of the elements hydrogen and oxygen. If the molecules of a substance are composed of one or more elements in chemical combination, the substance is called a "compound." Compounds can be broken down into their constituent elements.

c. Scientists formerly recognized 92 elements. Today, many more are identified. In fact, a stable elementary atom is known for every mass number from 1 up to 210. They are the elements of which all compounds are composed. They are characterized by their atomic masses and chemical and physical properties. Some elements have similar chemical properties but possess *different masses*. They are called "isotopes"; other groups possess equal masses, but individuals in the group have different chemical properties and consequently different atomic numbers. They are called "isobars."

d. Elements can be compiled in an orderly fashion, according to their atomic weights and chemical properties. This compilation is called the "Periodic table." The first compilation of this sort was published by Mendelejeff. The lightest element, hydro-

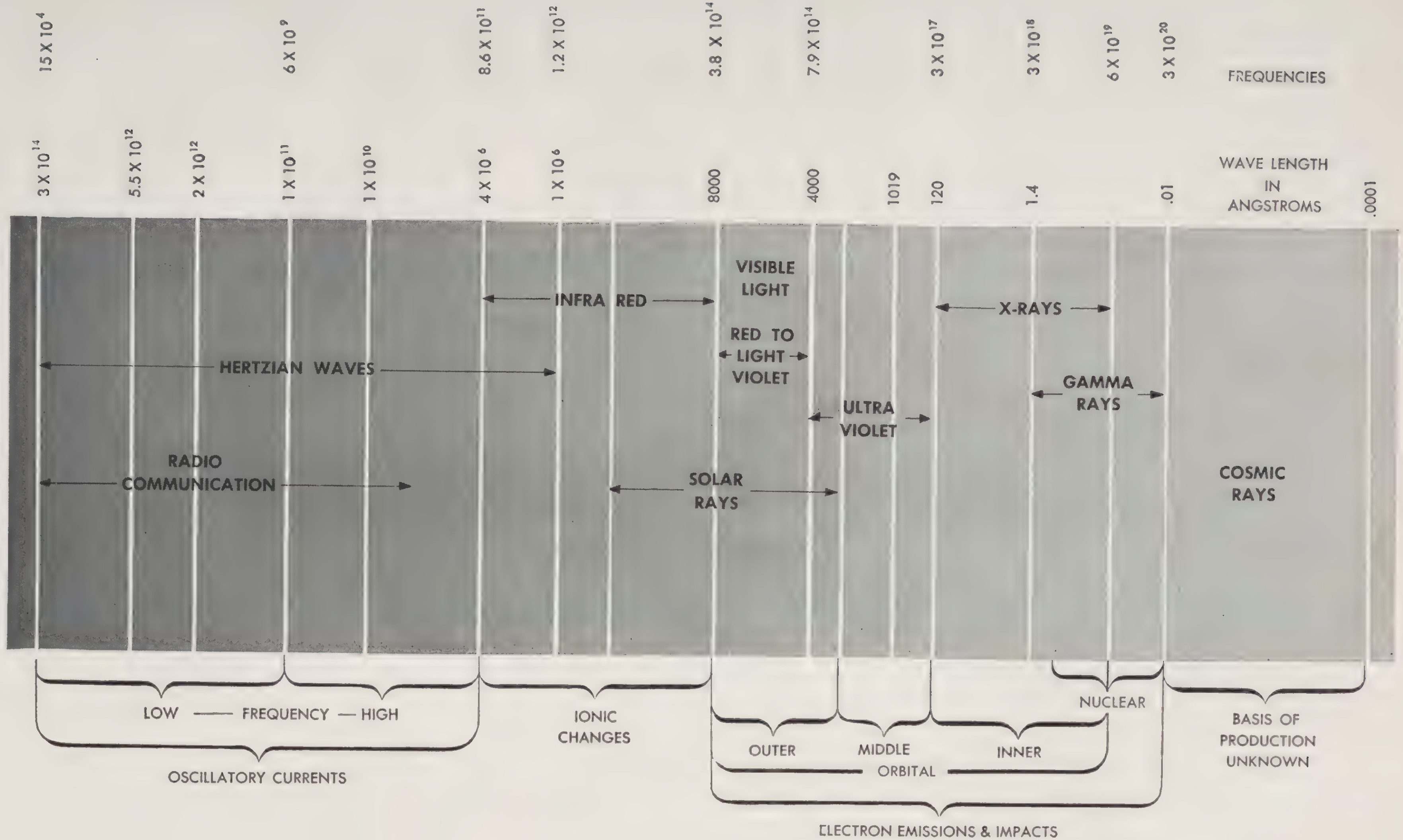


Figure 2. Electromagnetic spectrum.

gen, was given the number 1 position in the table, while the heaviest element, uranium, the number 92.

e. Atomic number is determined by the number of protons in the nucleus or the number of electrons in the orbit. Oxygen has the atomic number 8. It has been assigned an arbitrary weight, 16, called the atomic weight. Atomic weight varies, depending upon the number of protons and neutrons in the nucleus. Relatively, oxygen being assigned 16, hydrogen has an atomic weight of 1.008, and uranium an atomic weight of 238.17.

f. An example of an isotope is heavy hydrogen, it having chemical properties identical with ordinary hydrogen, but different atomic weight. It was recently discovered, and was found to be twice as heavy as ordinary hydrogen. The atomic weights of most elements represent mixtures containing both the ordinary elements and the isotopes.

g. A molecule may be composed of a single element in which case when divided into the smallest parts it still maintains all the physical and chemical characteristics of that element—that smallest part is called an "atom." Some molecules are composed of one element—as for instance, a molecule of hydrogen (H_2). Other molecules consist of two or more elements—as for instance, a molecule of water which contains two atoms of hydrogen (H) and one atom of oxygen (O).

h. Modern physics has shown that atoms, like molecules, are composed of definite constituents called "electrons" and "protons." In the nuclei of all but hydrogen there are also contained neutrons. These three are probably the smallest indivisible entities of matter. All electrons are alike, regardless of the atom in which they exist. An electron in the hydrogen atom is identical with an electron in an oxygen atom. In fact, an electron may find itself in a hydrogen atom at one instant, while shortly afterwards it may be in an oxygen atom or some other atom. To some extent, it is believed that there occurs an interchange of electrons between atoms. All protons are identical and indistinguishable, one from another; all neutrons are identical, regardless of what atom they may occupy. Protons and neutrons, however, probably are not *freely* interchangeable with different atoms. One element differs in characteristics from another element merely because of the number and arrangement of the electrons, protons, and neutrons contained in their respective individual atoms. Thus, all atoms are composed of the same essential "building blocks."

i. Studies have indicated that the electron is the smallest measured quantity of negative electricity. (See table I, app. V.) Electrons have mass, occupy space, and repel each other with force which is inversely proportional to the squares of the distances between them.

j. A proton is the smallest measurable quantity of positive electricity. Protons are about 1,800 times heavier than electrons; they, too, occupy space. Protons repel each other. Protons and electrons attract each other.

k. Neutrons, the most recent addition to atomic constituents, have mass (equal to that of protons); they occupy space but are electrically neutral. It is believed that neutrons possess equal quantities of negative and positive electricity.

l. An atom is described as a miniature planetary system; its nucleus being analogous to the sun, while electrons, revolving about it, are analogous to the earth and other planets. (See fig. 3.) The nucleus of an atom (other than hydrogen) is composed of one

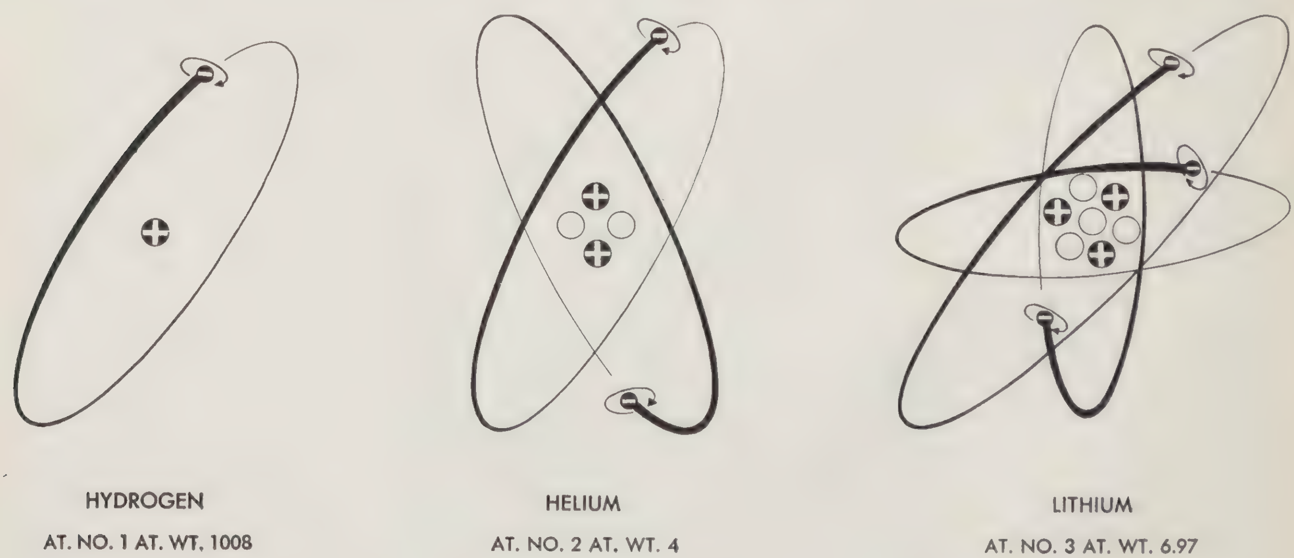


Figure 3. Chemical cell.

or more protons and neutrons. Since a proton and a neutron each is approximately 1,800 times as heavy as an electron, almost the entire mass of an atom resides in its nucleus. It is conjectured that electrons revolve about the nucleus in definite orbits. The forces of attraction urging the electrons toward the nucleus are balanced by the centrifugal force, which urges them away from the nucleus. In the stable atom these two opposing forces are equal, and so the electrons remain fixed in their orbits. Only by outside influence can these forces be disrupted and the atom be disintegrated. Electrons may be moved out of one orbit and into another orbit, or they may be removed entirely from the atom. This disruption of atomic structure is only momentary; the electrons are quickly restored, and the atoms return to their normal conditions. Radioactive elements, such as radium and thorium are exceptions. These disintegrate, when the equilibrium of atomic forces is momentarily destroyed through some as yet unknown and unexplainable reason. As a consequence, these atoms are broken up, with emission of corpuscular rays (alpha and beta particles) and very short waves described as *gamma* rays.

m. A normal atom of any element is electrically neutral. In its nucleus there are, therefore, protons equal in number to the orbital electrons. The nucleus also contains neutrons, sufficient in number to make up appropriate atomic weights. Electrons, and possibly neutrons, too, are the smallest indivisible units of matter. The electron is the smallest unit of *negative* electricity; the proton is the smallest unit of *positive* electricity. Electrons, protons, and neutrons are the "building blocks" of atoms. Atoms are the "building blocks" of molecules, and molecules are the constituents of all things, whether living or dead. Such is the modern theory of the electrical structure of matter.

8. ELECTRICITY. a. "What is electricity?" Answer to that question is usually an evasive one. Clear outright answers are seldom given. The reason is that electricity cannot be seen. Electricity makes itself known only through the effects it produces. For example, electricity manifests itself through the production of heat. The electric light bulb "lights"; the plate of an electric stove gets hot. Electricity produces magnetism. It "rings" the door bell. It "runs" our clocks, radios, and trains. Electricity is measured, as will be seen later, by means of these effects.

b. Physicists discovered, about 2,000 years ago, that amber rubbed with silk acquires the power to attract to itself small, lightweight bodies, such as bits of paper, pith-balls, etc. The amber was said to be electrified by frictional contact with the silk. It was charged with "static" electricity. Later, it was discovered that other bodies, also, could be charged by frictional contact. Wax rubbed by wool, glass rubbed by silk, and many other combinations, displayed similar properties—those of electrification. Small bits of paper were noted to be attracted to amber, but repelled by wax. Other objects were repelled by amber, but attracted by wax. Two conditions of electrification were demonstrated. In order to distinguish between them, amber and wax were said to be charged with positive (+) and negative (−) electricity, respectively. These fundamental observations of electrification are as true today as they were hundreds of years ago, when they were first observed. The present picture of electrification, however, is a bit more complete, thanks to the discovery of the electron and to the developments of modern theories of the electrical structure of matter. Amber rubbed with silk is pictured as having lost some of its electrons to the silk, thus, being left with unbalanced protons—explaining "positive electricity"; whereas, wax rubbed with wool takes electrons from the wool and thereby becomes charged with "negative electricity." Electrification is, therefore, a redistribution of electricity in substances which already contain electrical charges. There is not the creation of new charges.

9. CURRENT. a. General. An electric current is the *motion of electrons* (and protons), whether that motion is in a copper wire, in air, in water, or in living tissues. Electrons and protons may move free of other entities of matter. They may become attached to neutral atoms or molecules and the latter move with them. In such instances, the characteristics of the atom or molecules are altered thereby. They are "charged" by way of potentials described as "valences." These atoms or molecules are then called "ions." Moving ions (probably existing only in gases and liquids) also constitute electric currents, possessing all the properties of any other current. Protons and ions are more bulky than electrons. Their movements, therefore, are more sluggish. For this reason, it is likely that in solids, electric currents are solely the movements of electrons.

b. Electron—atomic structure and ionization. The relationship of the electron to the structure of atoms and to ionization and electrical currents is well exemplified by way of a chemical cell. Figure 4 demonstrates the principles of a chemical cell. There is a zinc terminal and a copper terminal. If only one of these be immersed in a solution such as sulphuric acid, there is no appreciable effect. Likewise, if the two be immersed and are not in apposition or connected by an electrical conductor (such as a copper wire) again, there is no appreciable effect. However, if the zinc and the copper be immersed and connected as shown in the diagram or if they are in contact with one another, very significant changes result. Hydrogen gas will be given off, particularly from the copper terminal and there will be dis-

integration of the zinc. This is explainable on the basis of electron loss by the atoms of the zinc without there being replacements of these electrons and without there being a complete electrical circuit. The electrochemical reaction is believed to be as follows: the sulphuric acid solution contains H^+ (hydrogen ions) and $SO_4^=$ (sulphate ions). Zinc atoms are converted into Zn^{++} (zinc ions). The positive hydrogen ions are attracted to the negative copper terminal where, when there is provided an electrical connection between the zinc and the copper they produce an attraction force for the electrons which have been liberated from the zinc atoms. Thus, electrons are propelled from zinc to copper by virtue of a propulsion force exerted by the sulphate ions and an attraction force exerted by the hydrogen ions. The hydrogen ions actually attract the electrons to the extent of uniting with them, thereby being converted from hydrogen ions to hydrogen atoms (H^+ to H). Two atoms of hydrogen are then evolved as a hydrogen molecule (H_2), explaining the evolution of gas from the copper terminal. The important consideration is that the electrons concerned with this conversion of hydrogen ions into hydrogen atomic structure, are not returned to the zinc. There is an *incomplete* electrical circuit. The zinc has lost some of its atomic structure, the electron, and goes into the solution as zinc sulphate. As a result of this disintegration of the zinc, terminal occurs.

c. Electrons, ionization and electrical circuits. The conception of electron mobilization and electron separation from atomic structure as above described, with resultant ionization appears to be pertinent to electrical currents in general. However, the electron conductor (copper) in the case of currents concerned with the usual electrical supply does not disintegrate. Though there may be transient ionization of the atoms in the ordinary conductor, the ions recombine with electrons to reestablish their atomic structures because of there being a *complete* circuit for the electrons.

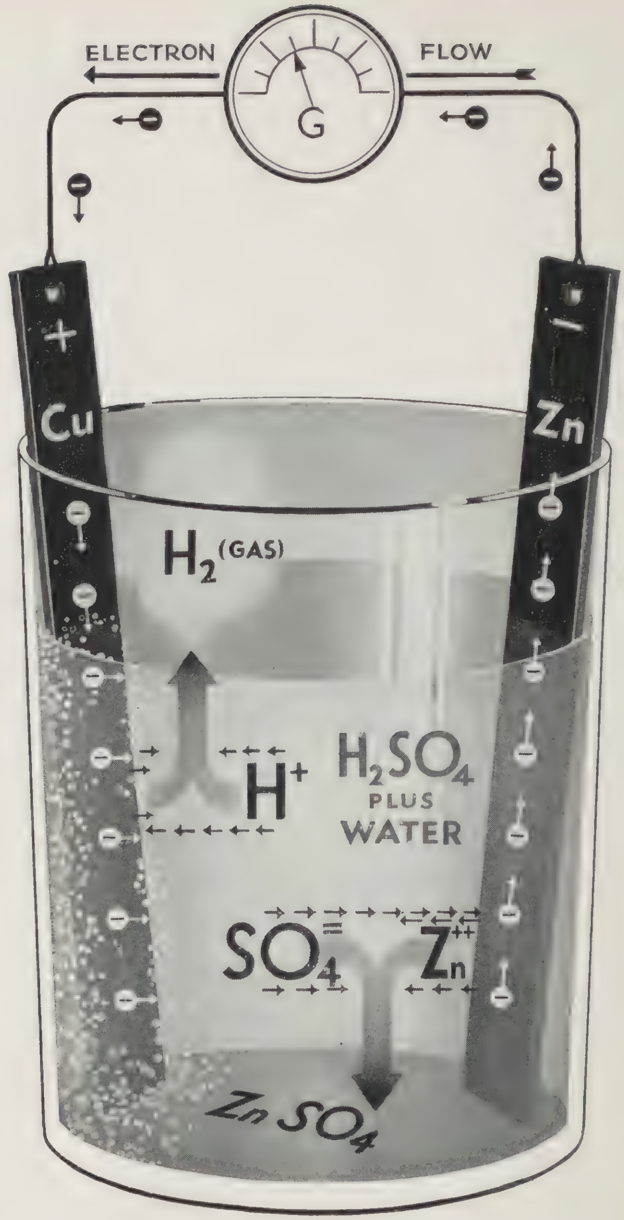


Figure 4. Hypothetical atomic structures.

10. QUANTITY OF ELECTRICITY. The unit of quantity of electricity is the coulomb. One coulomb is equal to 60×10^{17}* electrons. A coulomb of electricity flowing through a cross section of a wire each second is one *ampere* of current. (See table III, app. V.) A *milliampere* is equal to .001 ampere.

11. ELECTROMOTIVE FORCE. a. An electromotive force (emf) is any influence, that is, pressure, which will put *electrons* (or protons) into motion. It may also stop them.

b. Electromotive forces may be established by five different methods: friction between dissimilar substances; chemical action; thermoelectric action; contact between unlike substances and, electromagnetic induction. In each of these methods, the net result is the mobilization of charges of one sign (electrons), leaving an equal number of charges of the opposite sign (protons). The resultant force of attraction constitutes an emf.

c. The practical unit of emf is the volt. A *kilovolt* is equal to 1,000 volts.

12. RESISTANCE. a. The passage of an electric current through a substance is impeded by friction. It is hindered also by the binding forces which some atoms and molecules display toward electrons. These factors

*60×10^{17} = 6,000,000,000,000,000,000.

are not equal in all substances. If they are small, the substance is said to be a good *conductor* of electricity. If they are large, the substance is said to be a poor conductor of electricity—or an *insulator*. In either case, the opposition to the flow of current is called "resistance." Segments of materials which offer great resistance to the flow of electrons are called "resistors." A simple resistor may consist of several coils of wire wound on porcelain or hard rubber. Some resistors have movable contacts so that various portions of the total resistance can be used. (See fig. 5.) The practical unit of resistance is called the "ohm." An emf of one volt will move a current of one ampere against a resistance of one ohm.

b. The resistance of a wire depends upon its size, length, and the material of which it is made. The resistivity (table IV, app. V) of a material is equal to the resistance in ohms of a piece of the material 1 cm. long, 1 cm. high, and 1 cm. wide. Resistivity of a conductor is low; that of an insulator is high.

13. OHM'S LAW. In 1826, Ohm discovered the fact that electromotive force necessary to propel a steady current in a given conductor is proportional to the current and the resistance; that is, $E = I \times R$, where E is the emf, I is the current, and R, the factor of proportionality, is the resistance. Ohm's law provides a method of calculating resistance. According to the preceding equation, $R = \frac{E}{I}$; that is, the resistance of a conductor is numerically equal to the emf divided by the current.

14. POTENTIAL DIFFERENCE. In order that electric current may flow from point to point along a conductor, there is a difference of potential from point to point in the conductor. This might be compared with the flow of water in a pipe or to the flow of heat in a substance. In water, a difference of pressure between points in the pipe must exist, if the water is to flow. Likewise, heat flows only if there is a difference of temperature between points in the substance. The potential difference across the ends of a conductor is, by Ohm's law, the product of the current and resistance of the conductor. The practical unit of potential difference is the *volt*.

15. ELECTRIC CIRCUITS. Ohm's law, applied to a completed electric circuit (dc) states that the sum of the potential differences of various parts of the circuit is equal to the emf of the circuit. Thus, in the circuit shown in figure 5 a portion of the battery's emf is required to propel the current through the battery, the rheostat, the lamp, the switch, and the wires. The lamp, the switch, etc., all offer resistance to flow of the current. However, there is no "piling up" of current in any portion of the circuit; the current in any one part of the circuit at any instant is equal to the current in all other parts of the circuit. Moreover, when the switch is "open," even though there be an emf across the battery terminals, no current flows in the circuit. Electricity flows only in completed circuits.

16. SERIES AND PARALLEL RESISTANCES. In figure 5(a) the resistances represented by the lamp (R_5), rheostat (R_2), meter (R_3), etc., are connected in "series." The total resistances (R) of the circuit is equal to the sum of the separate resistances. Thus $R = R_1 + R_2 + R_3 + R_4 + R_5$. Other circuits may have two or more resistances connected in "parallel," as in figure 5(b). The total resistance (R) of this circuit is $R = \frac{(R_2 \times R_5)}{R_2 + R_5} + R_3 + R_4 + R_5$. Thus the total resistance of the *parallel arrangement* is $\frac{(R_2 \times R_5)}{R_2 + R_5}$. No reference has been made to the resistance of the wires of these circuits. In general, the wire resistance is small compared with the total resistance of the circuit, and therefore, the wire resistance can be assumed to be equal to zero. (Table V, app. V defines diagrammatic symbols.)

17. ELECTRIC POWER. Electric power, or any type of power, is defined as the rate of doing work. When electrons are in motion, work is done. The rate at which this work is done is by definition equal to the product of the emf and the current; that is, power, equals volts times amperes. The practical unit of power is the "watt," and the meter which measures electrical power is called the "wattmeter." One volt propelling a current of one ampere represents one watt of power.

18. HEATING EFFECT OF CURRENT. The flow of electrons in a resistance, whether the latter be a copper wire, some water, or a portion of tissue, will produce heat. Experiments have shown that the amount of heat produced is proportional to the product of the current squared and the resistance. Thus, heat produced (H), $H = k \times I^2 \times R$, where k is a constant of proportionality, and the numerical value depends upon the particular units in which H is to be expressed. H may be given in calories per second; if $k = .239$, I is given in amperes, and R is expressed in ohms. If the heat production is slow, and if the resistance element loses this heat rapidly, the temperature of the resistor may not be increased appreciably. If however, reverse conditions exist, the resistor's temperature may increase to the melting point. This is what happens when wires, meters, etc., are "burned out." The metal carrying the current is melted.

19. MAGNETISM. a. Magnets. The popular idea of a magnet is a piece of iron, bar shaped or horseshoe shaped, which has the power to attract and hold to itself small pieces of iron. This attraction power

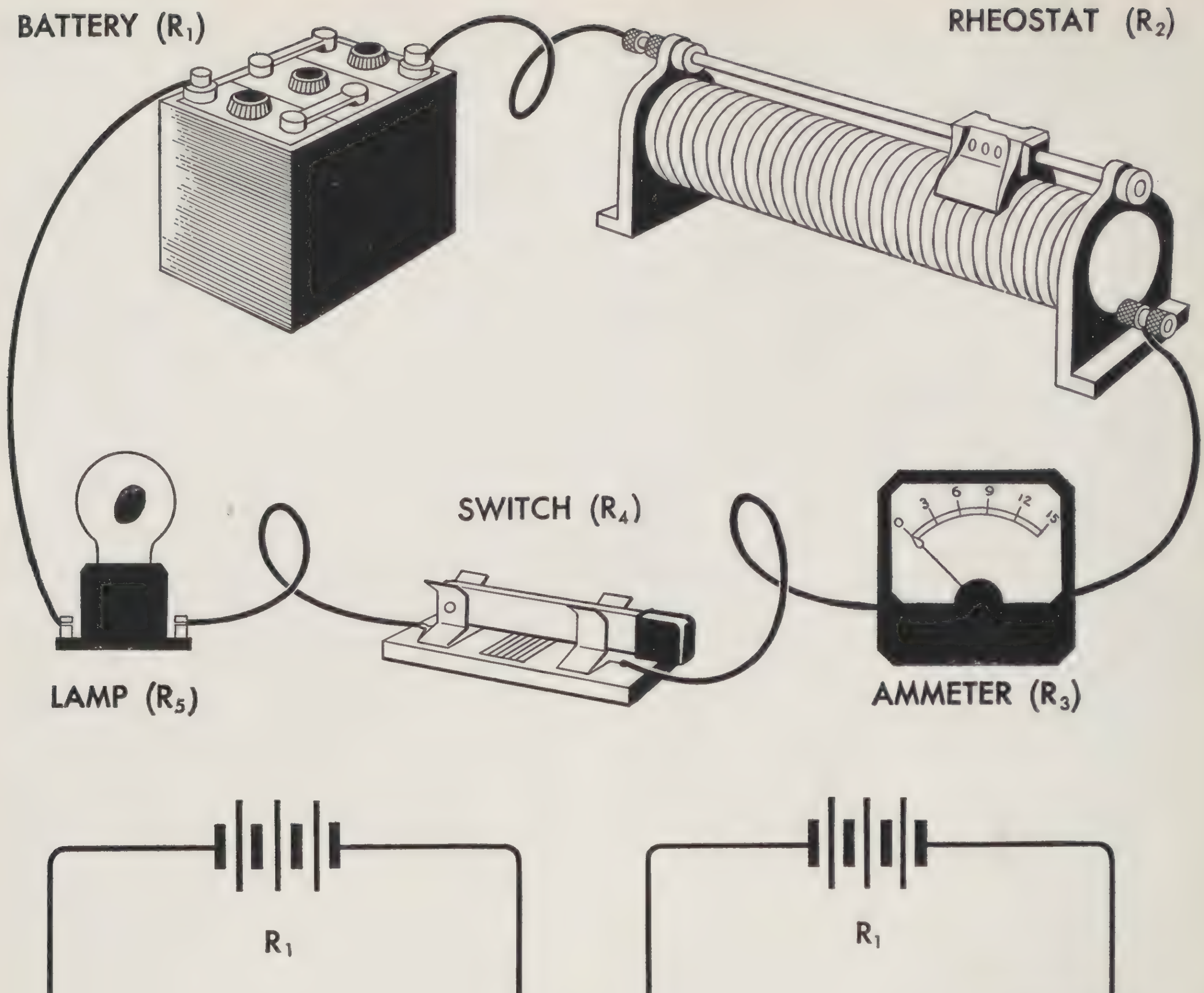


Figure 5. Types of electric circuits.

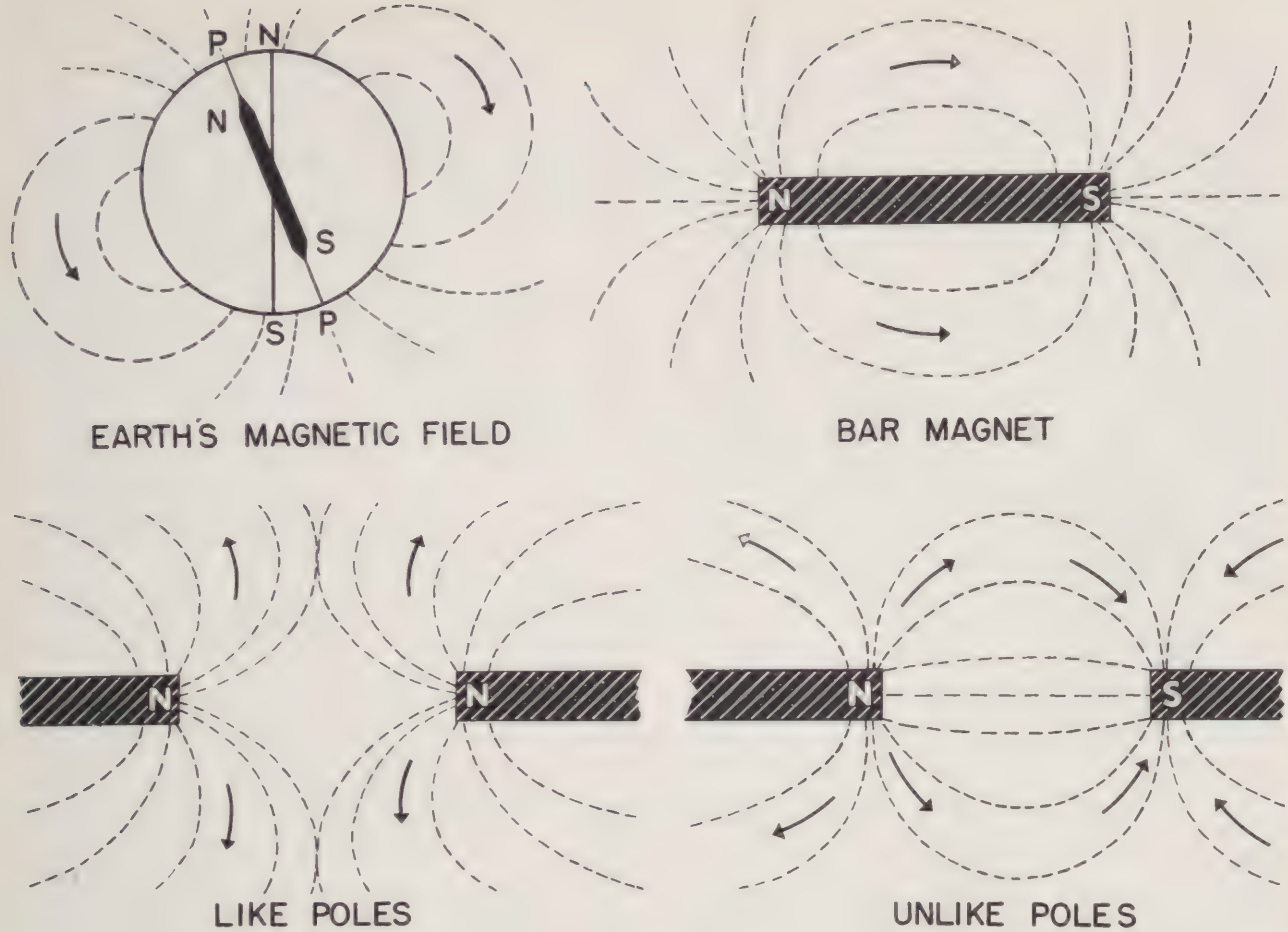


Figure 6. Magnetic field.

appears to be concentrated near to the ends of the bar. These areas are called "poles." The iron bar is said to be magnetized, or to possess magnetism, and it is called a magnet. Certain natural ores possess these properties; they are called "lodestones." A compass needle is a bar magnet. The end of the needle which "points" north is said to have a north-seeking pole; the opposite end is said to have a south-seeking pole. Experiments show that the north poles of two compasses repel each other, and that south poles likewise repel each other. The north pole of one magnet attracts the south pole of the other. The fact that a compass needle always orients itself in a north-south direction, indicates that the earth is a huge magnet, with magnetic poles (P,P') near its north and south geographical poles. (See fig. 6.)

b. Magnetic fields. In the space around a magnet, whether it be a bar magnet, a compass needle, or the earth, there is a field of force. A small compass needle will assume very definite positions or orientations, not only to the earth's magnetic field of force but also when placed at different points in the space around a bar magnet. If these positions are sufficient in number, their locations can be connected in fairly uniform, regular lines. These lines appear to emanate from the poles of the bar. They are the paths of *magnetic poles*, if the latter were free to move. They are called "magnetic lines of force," and the sum total of them is called the "magnetic field." The intensity of the field is defined as the force on a "unit pole." The unit of field intensity is called "gauss." By convention, a *magnetic field* of one *gauss* intensity has one magnetic line of force perpendicular to each square centimeter of cross-section.

20. ELECTROMAGNETISM. a. Electric current and magnetic field. Oersted, in 1820, discovered that electric currents exhibit magnetic effects. A compass needle held close to a straight wire carrying a direct current, will turn perpendicularly to the wire and current. If the needle is moved from above the wire to a similar position below the wire (fig. 7), the needle will turn through 180° and come to rest, again

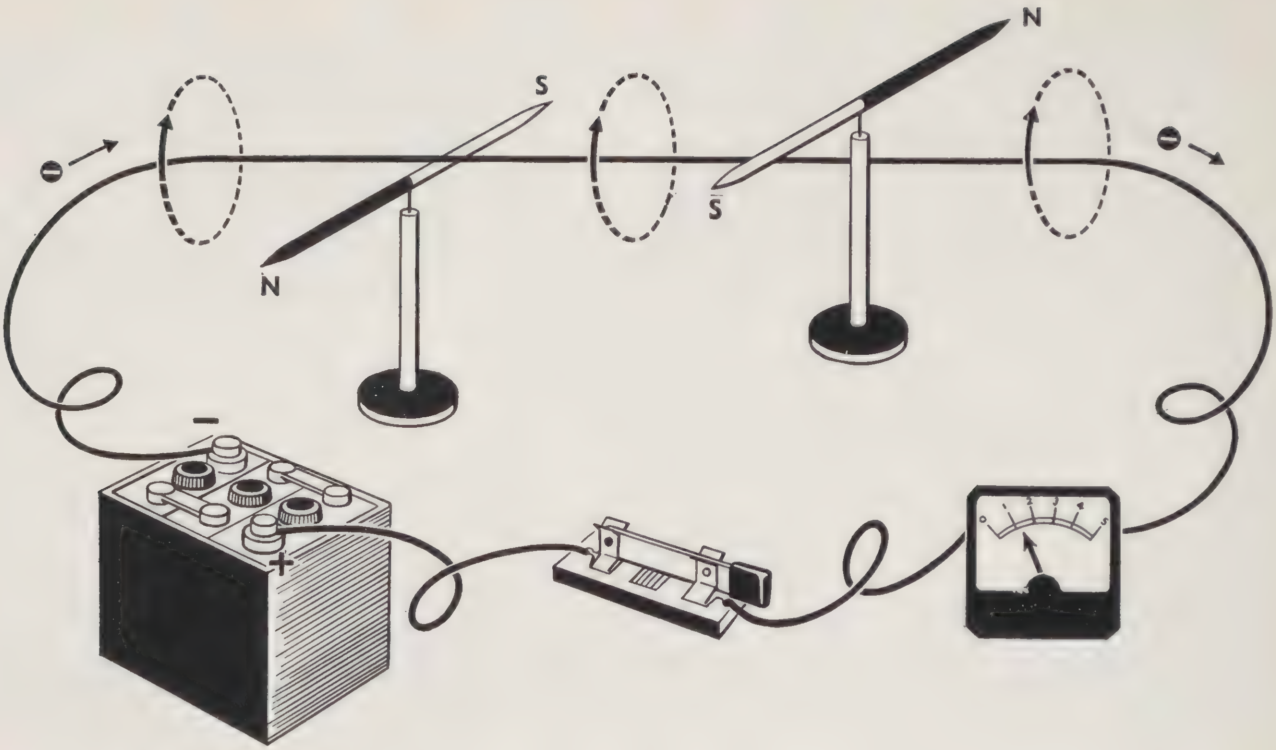


Figure 7. Magnetic field of force about a conductor (electron flow).

perpendicularly to the wire. These observations indicate the presence of a magnetic field, about a conductor when carrying an electric current. Further experiments show that the magnetic field encircles the conductor. An arbitrary rule has been adapted for specifying direction of current and direction of magnetic field. If the wire is grasped with the right hand and the thumb extended in the direction of the current, then the fingers will indicate the direction of the magnetic field. When Oersted made his discovery, electrons were unknown and for that reason the direction of current, described thusly, is opposite to the present day conception of the direction of flow of electrons. Today, we should speak of the left-hand rule, applying it in a manner opposite to that described above. (See fig. 8.) It is probable that each moving electron creates its own magnetic field of energy. There is no electron motion without this attendant field of energy, and electrons continue to move until the magnetic field has disappeared. This is the modern theory of magnetism. The strength of the magnetic field of energy about an

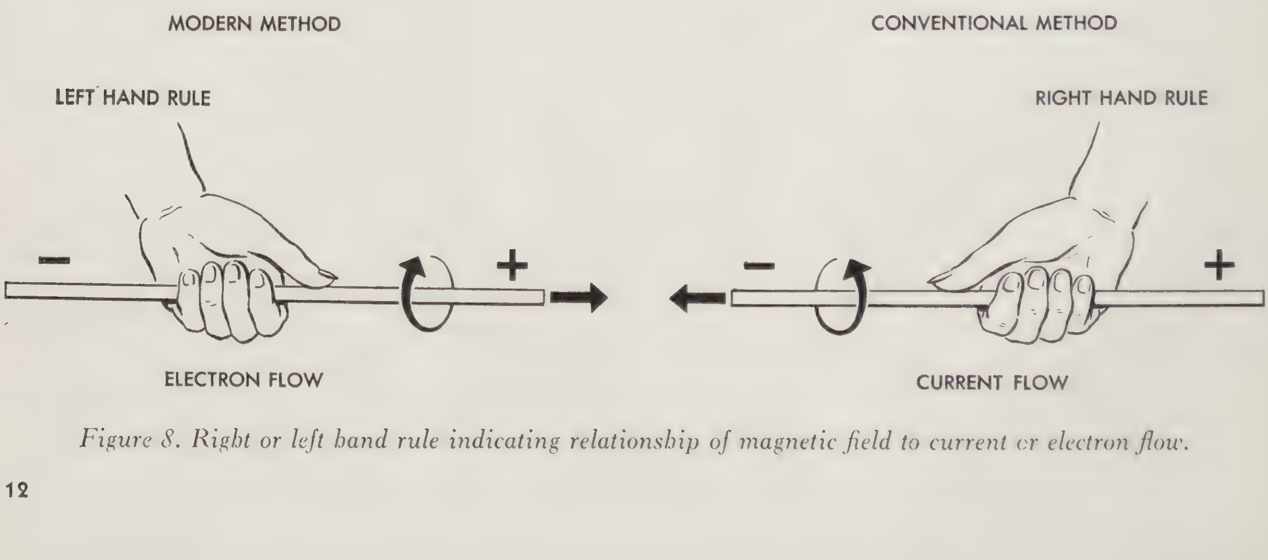


Figure 8. Right or left hand rule indicating relationship of magnetic field to current or electron flow.

electric current increases as the current increases. In fact, currents are measured in some instruments by determining the magnetic field strength.

b. Electromagnets. (1) Certain materials become magnetized when they are in magnetic fields. Of these, some, such as soft iron, offer little opposition to the magnetic effect, and retain little of it when removed from the field. Others, steel for example, offer considerable opposition to magnetization, but retain most of it when removed from the field. The latter are "permanent" magnets. Magnetization is accomplished in this manner by magnetic induction.

(2) There are two types of electromagnets; air core and iron core. The air core type is a *solenoid* consisting of turns of wire in air; the iron core type consists of a coil of wire surrounding an iron core. (See fig. 9.)

(3) The air core type of electromagnet behaves just as an ordinary magnet. A magnetic field is created about each of the turns with a definite polarity—that is, a north and south pole are established.

(4) The iron core type behaves similarly as the air core electromagnet but the magnetic field is intensified. The iron core becomes magnetized and contributes to the field effect. As long as the current flows in the coil, the electromagnet has all the properties of a magnet. When the current ceases to flow, the coil, and hence the core, loses the magnetism. Any lag in the loss of magnetism by the core is called "hysteresis." If the direction of the flow of current reverses, then the direction of magnetization is also reversed.

(5) The principle of the electromagnet is utilized in many devices in an X-ray circuit, such as in relays, circuit breakers, remote control switches, and releases and contactors in the X-ray timing circuit.

c. Electromagnetic induction. Michael Faraday discovered, in 1831, that variations of current in a circuit would produce an emf in a neighboring circuit. This phenomenon occurred even though there were no electrical connections between the two circuits. It is called electromagnetic induction. Experiments soon showed that the induced emf results from a changing magnetic field. Emf's may be induced in conductors when the conductor is moved in a field of constant strength, when the conductor is stationary and the magnetic field strength varies, or when the conductor moves and magnetic field strength varies.

d. Lenz's Law. A bar magnet undergoes a force of repulsion when it is thrust into a solenoid in a closed circuit, and a force of attraction when removed from the solenoid. Likewise, a wire carrying a current is repelled when moving into a magnetic field; it is attracted when moving out of the magnetic field. These characteristics of electromagnetic induction are summed up in Lenz's law: the magnitude of induced emf is proportional to the rate of change of magnetic field strength, and, the direction of the induced emf is always such as to oppose the force of induction.

21. DYNAMOS AND MOTORS. a. The factors of movement, either of the magnetic field of force or of the conductor, is particularly well demonstrated by the functioning of a dynamo (electrical generator) or the principles of a motor.

b. One might consider a dynamo as a device designed to convert mechanical energy into electrical energy (though today, we think of electrical *energy* being produced because of the movement of actual particles of matter, the electrons). The mechanical energy referred to in this widely used definition is the energy which is expended in revolving the armature of the dynamo. Falling water, steam, or even another electrical source may be utilized. The essential consideration is that a portion of a metallic conductor, forming an open loop (the armature), constituting a small segment of a com-

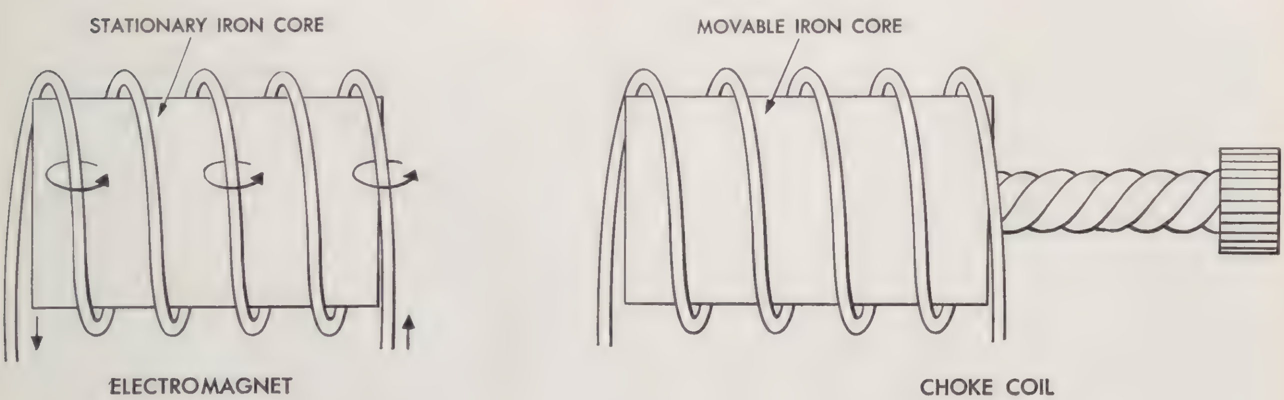


Figure 9. Uses of electromagnetism.

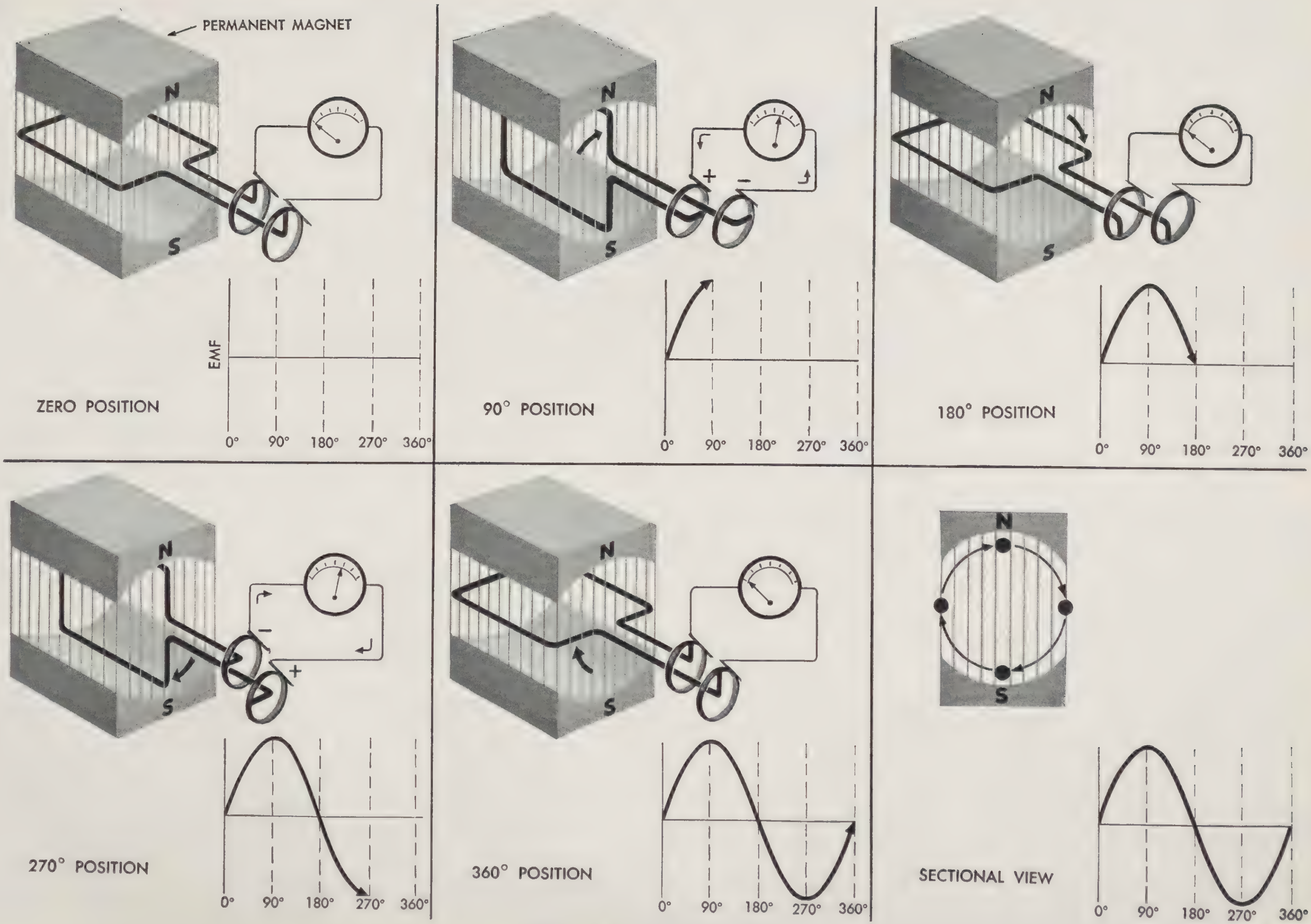


Figure 10. A simple a-c dynamo.

plete circuit, is mechanically revolved in a magnetic field. This open loop is positioned so that when revolving there results "cutting" of the lines of force of the magnetic field. As a result of this movement (of the armature in the field of force), electrons contained in the individual atoms of the armature are excited to move, and with a complete circuit, they travel through the commutator to the community line. The emf generated across the terminals of the armature is an alternating one, regardless of the type of commutator. As indicated in figure 10, either alternating-current or pulsating direct-current might be distributed by a dynamo, depending upon the design of its commutator. If two rings are used the a-c is connected to the line as alternating-current; if a split ring is used, the direction of distribution to the line alternates with each alternation of a-c and the result is a d-c in the line. The split ring commutator is merely a simple form of mechanical rectifier.

c. In contrast to the functional principles of a dynamo, a motor might be considered as a device designed to convert electrical energy into mechanical energy. Small direct-current motors usually have a ring type of armature. The action of the ring armature may be understood from the diagram. (See fig. 11.) Current from a battery is shown flowing in at the upper brush and out at the lower one. The effect of the current is to make each half of the ring a magnet with a north pole at the top and a south pole at the bottom. The attraction and repulsion between these poles and those of the field magnet cause the ring to rotate in the direction of the large arrows. In the alternating-current motor, the field magnet is an electromagnet. The magnetic field changes direction with each alternation of current and thus the forces of repulsion and attraction are varied synchronously with the result that the armature likewise travels in one direction. Thus, in the case of a motor, the motion of the armature is produced by the reaction of the magnetic field of the armature and the stationary magnetic field.

d. Just as dynamos may develop either alternating or pulsating direct types of current flow, depending upon the construction features of their commutators, so also motors may be designed for operation on either alternating or pulsating direct types of current flow, depending upon the construction features of their commutators and also, upon the field coils.

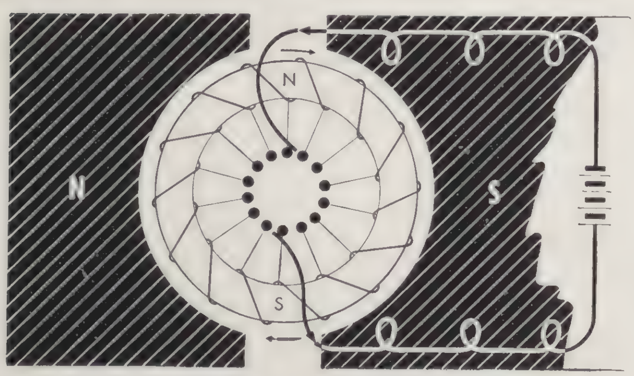


Figure 11. Direct-current motor.

22. TYPES OF ELECTRICAL CURRENTS. **a.** There are two general types of electrical currents: direct-current (d-c) and alternating-current (a-c). Each of these types is measured by meters designed appropriately—(that is, d-c versus a-c meters).

b. Two types of direct-current might be considered: continuous direct and pulsating direct.

(1) A continuous direct-current is produced by batteries. It is the type of current in which the electrons travel steadily in one direction and without change in magnitude. It is sometimes referred to as galvanic current.

(2) A pulsating direct-current may be produced by a dynamo or by rectification of alternating-current. With that produced by a dynamo the electrons move in one direction but not quite as steadily as in the case of a continuous direct-current. There is acceleration and deacceleration of electron movement. A pulsating direct-current, as produced by rectification, is often described as a "unidirectional" current. If there be actual movement of the electrons with every pulsation, the unidirectional current is described as "full-wave." If there be a suppression of every other pulsation (that is, alternation) it is described as "half-wave." With the use of the valve tubes (thermionic rectification), the waves extend practically from the base line to peak levels. Prior to the use of valve tubes this rectification was accomplished by the use of a rotating disk or cross arm terminals, in which instances only a portion of each wave became effective. These comparisons are shown in figure 12.

c. An alternating-current is produced by an a-c generator. The electrons move first in one direction and then in the opposite direction. There are increment and reduction as to the number of electrons flowing as considered in the case of pulsating direct-current.

23. ELECTRICAL CYCLE. The design of the dynamo and the speed of rotation of its armature govern its cycle performance. Referring to the simple dynamo in figure 10, it is seen that one complete electrical cycle is accomplished for each revolution of the coil. The term is usually applicable to alternating-current, in which case one cycle is equal to two alternations. In the same sense, in the case of pulsating direct-current, one cycle is equal to two pulsations. Today, most communities are supplied with 60-cycle current.

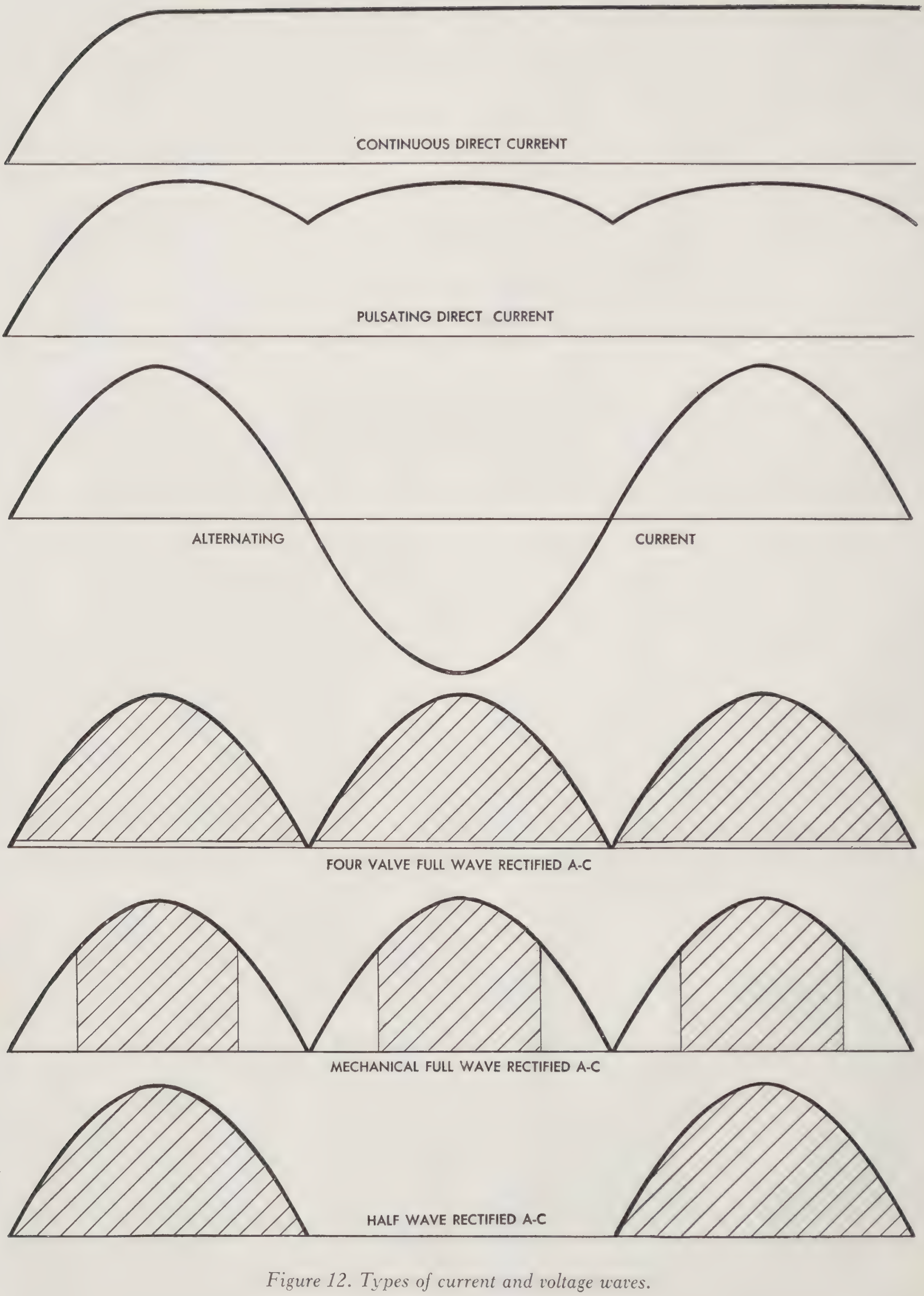


Figure 12. Types of current and voltage waves.

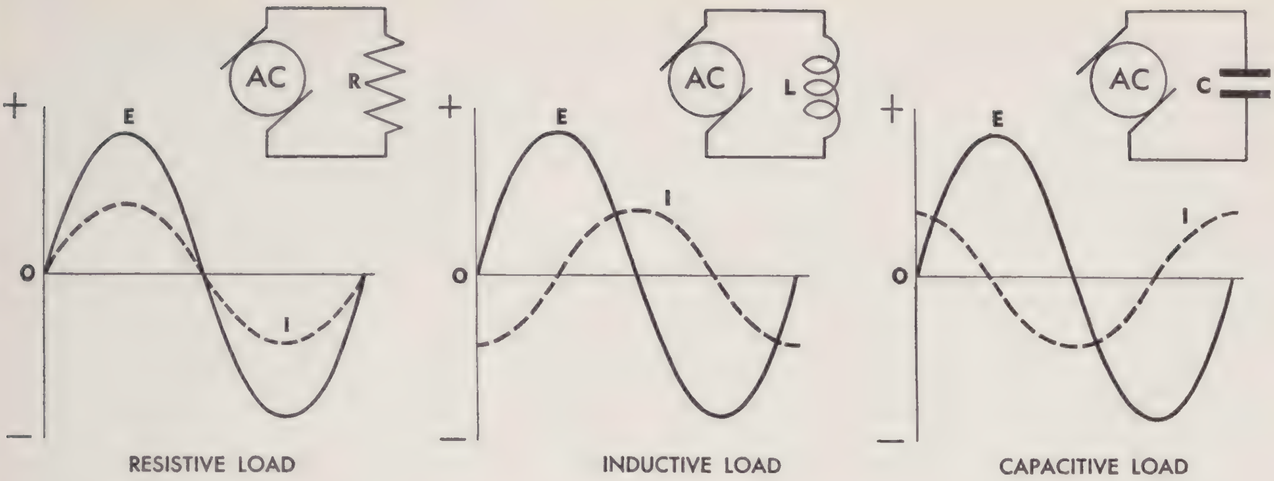


Figure 13. Phase relationships of voltage and current.

With such, there are 60 cycles per second; this is called the frequency of the current. Some communities are supplied with 50-cycle current. A few communities in the United States still utilize 30-cycle current, while in a few locations, for example the Canal Zone, 25-cycle current is used. Transformers and other component parts of X-ray equipment are designed and constructed to function on a particular cycle. Usually, when equipment is designed to function on a relatively low cycle current, it will also function with current of higher cycle, though not as efficiently. When equipment is designed to function with a relatively high cycle (that is, 60-cycle), and it is connected into a line of relatively low cycle (that is, 25-cycle), it is likely to burn out because the impedance of the transformers is insufficient. It is therefore important that the cycle of the electrical supply be known and that the design of the X-ray equipment be proper.

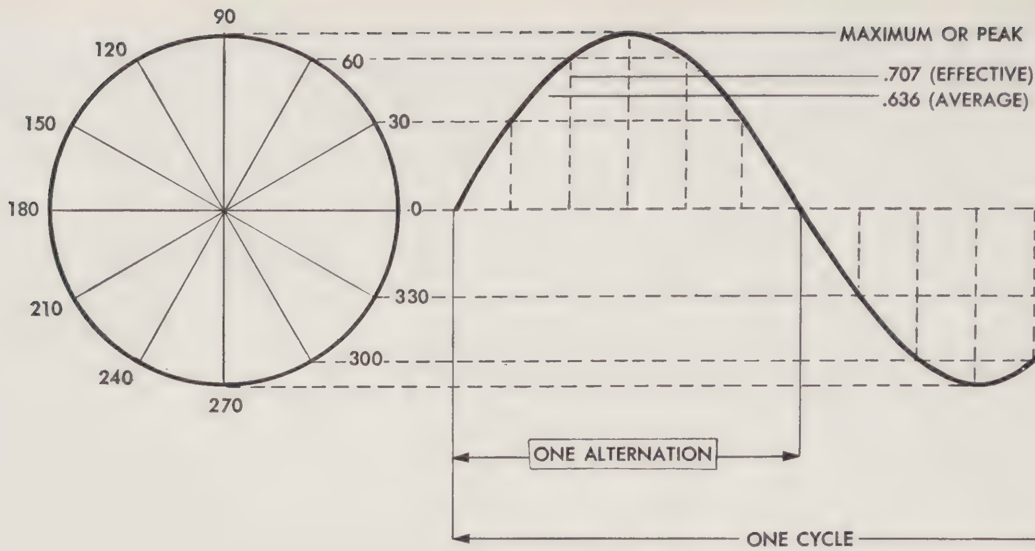
24. ELECTRICAL PHASE. a. The term "phase" may be applied for at least three connotations: description of a moment in either the voltage or current wave (more properly defined as "instantaneous value"); description of the synchronization or the lack of synchronization with respect to the voltage and current waves, in their entireties (fig. 13); and time relations with respect to power impulses as generated by a dynamo (that is, E_1, E_2, E_3, fig. 14). The usual application of the term pertains to this latter and it alone is being considered, here.

b. The design of the dynamo controls the phase performance with respect to power transmission. If the construction and positioning of its armature and magnetic fields are such as to produce two impulses per cycle, it is described as a single-phase generator (fig. 14a), and it is productive of single-phase electrical power. If more than two impulses are produced per cycle, the generator is described as a multi-phase generator. The most common type of a multi-phase generator is three-phase (fig. 14c). With this design, there are produced six impulses per cycle unit of time.

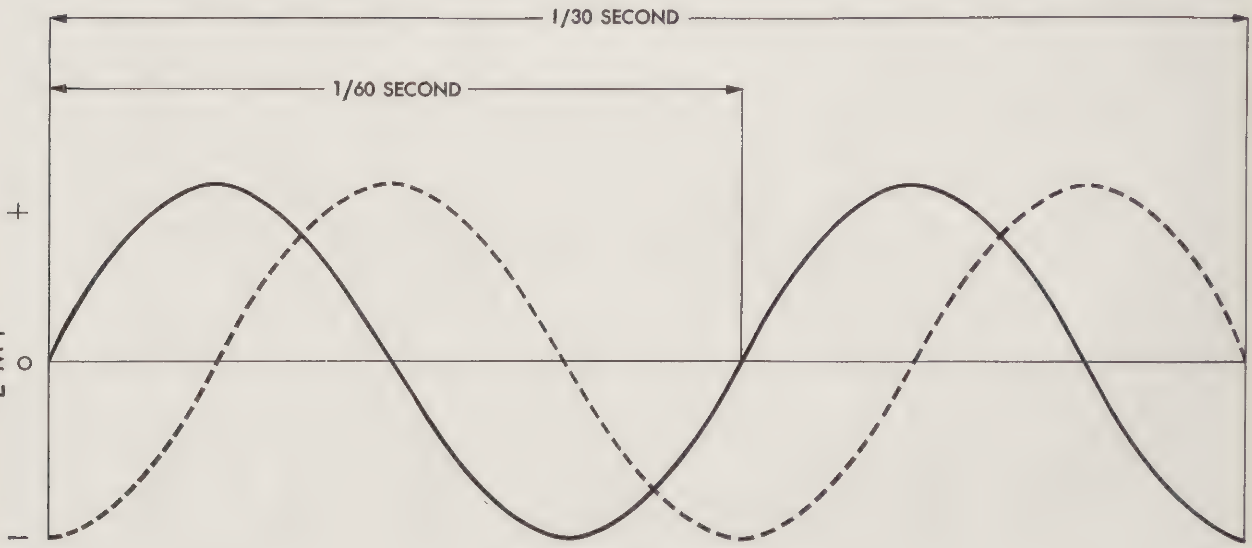
c. Single-phase electrical power is distributed by way of two or three wire leads. One of these three leads is a ground lead. (See par. 30.) Multi-phase electrical power is distributed by three- four- or six-wire systems. With the three or six-wire systems, no ground lead is included; whereas, with a four-wire system, one of the leads is a ground lead. In either instance, any pair of wires serves for circuit conduction of a single-phase current. Thus, a multi-phase generator is a distributor of more than one single-phase current; the maximum voltage and current values of each being attained at different moments of the cycle. Each single-phase power supply might be utilized separately.

d. It is more economical to use one three-phase generator and distribution system as compared with three single-phase generators and distribution systems of the same total power capacity. Therefore, three-phase distribution is common throughout the world. However, practically all X-ray equipment is designed for single-phase operation. Hence it is very important that multi-phase systems be identified and that connections to such provide for single-phase supply to an X-ray machine. (See par. 50.)

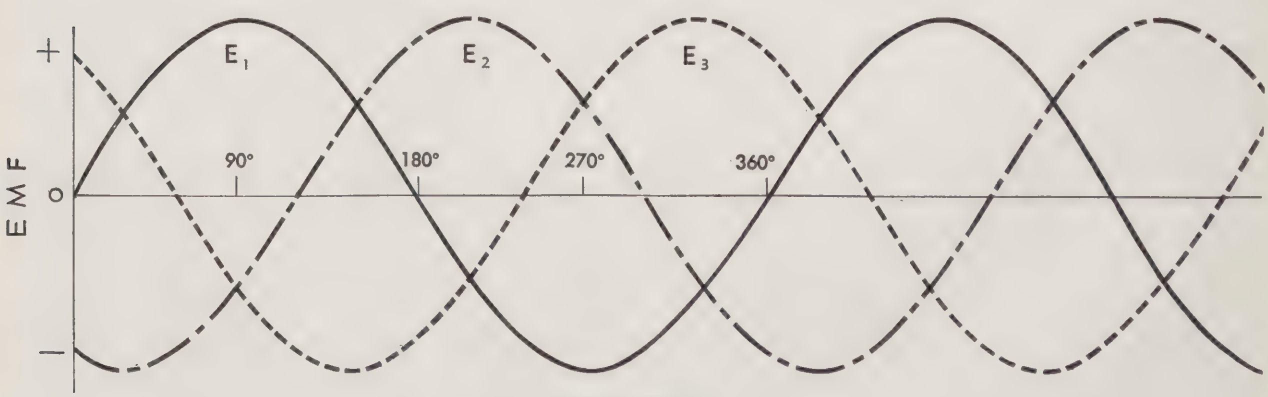
25. WAVE FORM. a. A graphical representation between time (or position of armature rotation) and current direction and magnitude is called the



a SINGLE-PHASE



b TWO-PHASE



c THREE-PHASE

Figure 14. True sine wave, showing its projection from the segments of a circle and the relative planes representing measurement values.

wave-form of the current. Similar graphical representations pertain to emf's. Thus, the wave form of a continuous d-c current is a straight line. (See fig. 12.) The wave forms of alternating and direct-currents are dependent upon mechanical construction of the dynamo and composite effects of the equipment utilized. The most desirable design of dynamo is one which gives a sine curve type of wave form. (See fig. 14a.) The peak or maximum points of the curves represent maximum currents or maximum emf's. Most current and voltage measuring instruments do not measure maximum values; instead, they measure either effective values or average values. The effective value of an alternating-current is equal to the value of direct-current which produces an equal effect, that is, equal heating effect in a wire. The average value of an alternating-current is zero (true sine wave form). If the wave form of a current is truly a sine wave, then the effective value of the current is equal to 0.707 times the maximum value, and the average value of one-half cycle is equal to 0.64 times the maximum value. The maximum, effective, and average values of a continuous direct-current are equal.

b. Knowing one of these values, in the case of a true sine wave, it is possible to compute either of the other two. The maximum value is equal to 1.41 times the effective or 1.57 times the average. The effective is equal to 0.71 times the maximum or 1.11 times the average. The average is equal to 0.64 times the maximum or 0.90 times the effective.

c. Considerable distortion of wave form is likely to prevail in the wave form of circuits having an inductive type of load, such as produced by transformers. Because of such loads, in the case of X-ray apparatus, the voltage wave may not coincide either as to time or shape with the amperage wave, in which case there would result distortion of summation (that is, power) wave form. Each X-ray unit might be considered to have its own particular high tension wave form. This explains some of the variations in roentgenographic performances. As much as 30 to 40 percent difference has been found in comparing the X-radiation performance of one unit with that of another, using identical technical factors and correcting for meter variations, etc.

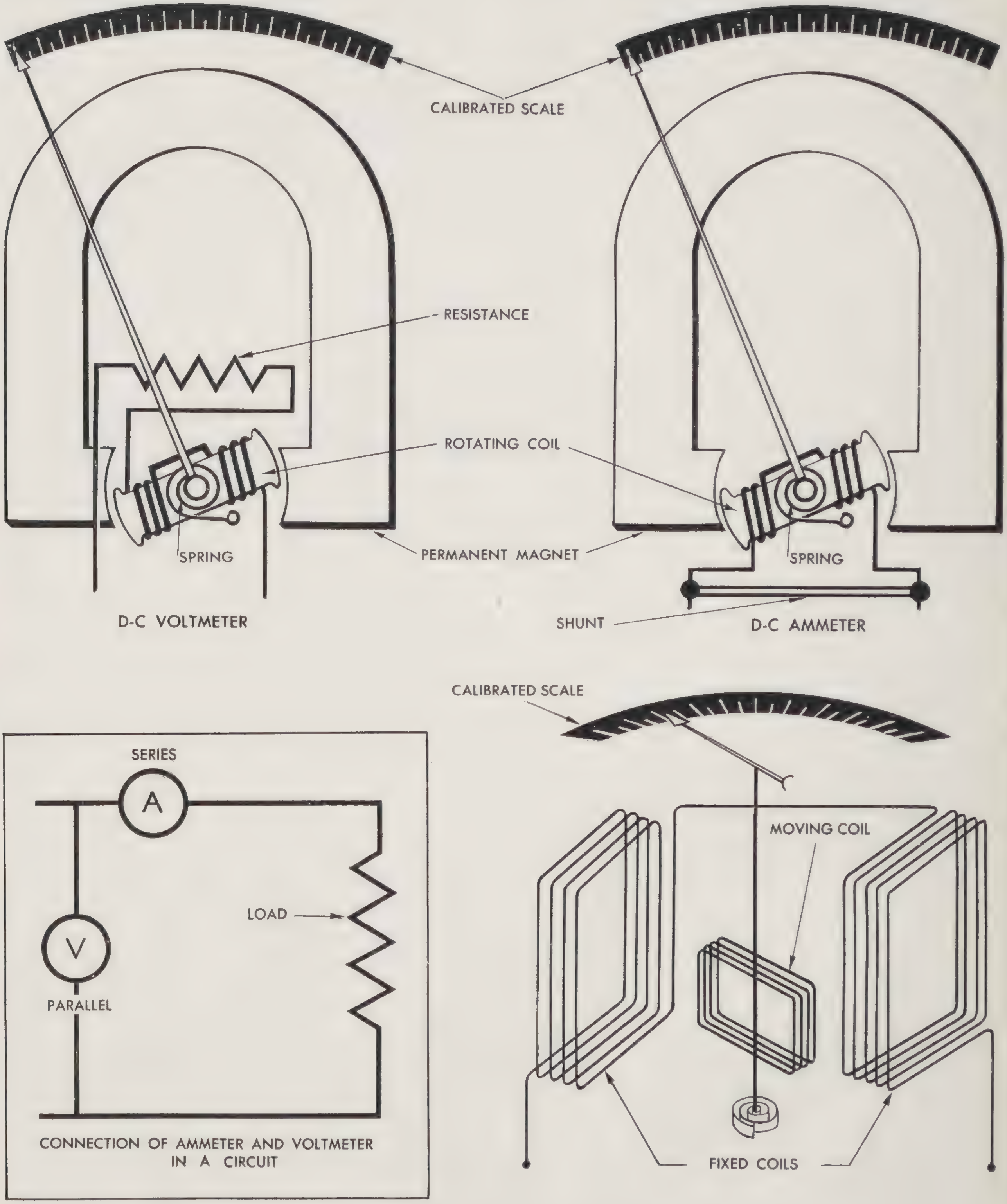
26. ELECTRICAL MEASURING INSTRUMENTS. Instruments which measure electric currents are called ammeters; those measuring voltages are called voltmeters. Each of these is designed to operate with either direct-current or alternating-current. Thus, there are d-c meters and a-c meters. D-c meters measure average values. All a-c meters, unless stated otherwise, measure effective values. The scale may be either linear or nonlinear depending upon the portion utilized. In the case of the nonlinear scale, the deflections are proportional to the square of the current. For this reason, with nonlinear a-c meters, currents producing small deflections cannot be measured as accurately as currents producing approximately full-scale deflections. (See fig. 15.)

27. CHOKE COILS. a. The magnetic field of force which is developed about a conductor carrying an alternating-current, tends to restrain the movement of the electrons. There is actually the paradoxical effect of a force tending to prohibit the very cause of its origin. This force is called a "counter emf." The results of a counter emf are essentially that of a resistance. The magnitude of the counter emf depends upon the degree of current flowing and also upon the shape of the conductor and the amount of magnetizable substance in proximity to it. For instance, a compact arrangement of coils of wire such as found in a solenoid, provides for great concentration of a field of force. If there be inserted into this field of force, a magnetizable substance such as soft iron or silicon steel, the already concentrated field of force will become intensified—as described in connection with electromagnets. If the magnetizable substance (the soft iron core) be made adjustable so that it can be partially or entirely moved into or out from the magnetic field of the solenoid the instrument is described as a "choke coil." (See fig. 9.)

b. Choke coils, then, are voltage regulating devices utilizing the principles of self-induction (counter emf) to control the flow of alternating current. With X-ray equipment they are used particularly in the primary circuit of filament transformers. There, they serve to regulate the voltage in the primary and therefore the voltage in the secondary circuit of the filament transformer. Thus, they control the current and hence the heating of the filament of the X-ray tube. For this reason, they are described as "filament regulators."

28. TRANSFORMERS. a. General. The physical effects described in connection with choke coils and electromagnets are utilized in the functioning of transformers. (See fig. 16.) The core of a transformer serves thereby to intensify the magnetic fields of the electrical circuits. There is no electrical connection between these two circuits. The design of a transformer is very much as if an electromagnet connected into one circuit were approximated to an electromagnet connected into another circuit. The approximation of these two electromagnet arrangements must be such that the field of force produced by the electrons moving in the one circuit will excite movement of electrons (in the opposite direction) in the second circuit. The first circuit, that originally containing moving electrons, is called the primary circuit; that, wherein electrons are excited to move because of the field of force due to the current of the primary circuit, is the secondary circuit.

b. Construction. Transformers consist of four essen-



Electrodynamometer for A-C and D-C Voltage and Current Measurement

Figure 15. Voltage and current measuring instruments.

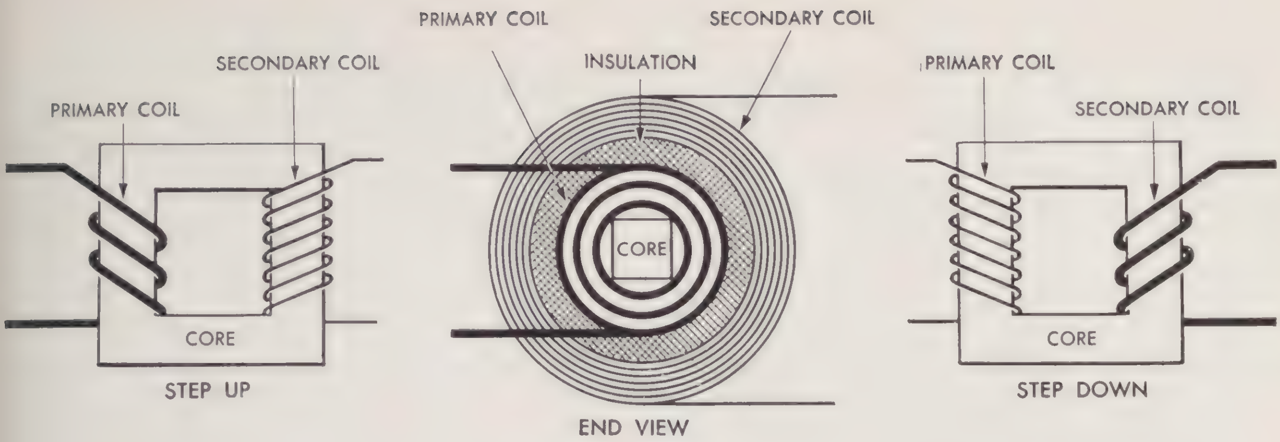


Figure 16. Transformer construction step-up.

tial parts: primary coil, secondary coil, core, and insulation. (See fig. 16.) The core is made of an alloy of iron, either round, rectangular, or cylindrical in shape. The primary coil (copper wire) is wound around one arm of the core; the secondary (copper wire) may be wound around the same arm, or it may be around a different arm. In either case, the primary and secondary coils are connected magnetically by the iron core. They are not connected electrically, however, at any point, one with the other. Rubber, baked enamel, cloth, and other types of insulators cover the wire of the coils. The coils themselves are insulated from each other and from the core by wood, porcelain, glass, mica, and other types of insulators. The coils and core are immersed in transformer oil which provides further insulation.

c. Step-up. When the number of turns in the secondary winding is greater than the number of turns in the primary winding, the transformer is described as a "step-up transformer." This term refers to increase in the voltage across the secondary coil and thereby, also, of the secondary circuit; as compared with the voltage across the primary coil. The voltage of the secondary circuit bears a relationship to the voltage of the primary circuit approximately as the number of turns in the secondary winding bears a ratio to the number of turns in the primary winding.

d. Step-down. When the number of turns in the secondary circuit is less than the number of turns in the primary circuit, the result is the opposite. There are then fewer turns of conductor in the secondary circuit to be influenced by the fluctuating field of force of the primary, and as a consequence there is a reduction in voltage across the winding (coil) of the secondary winding as compared with that of the primary winding. This is the arrangement in a "step-down transformer." The term "step-down" refers to a decrease in voltage.

e. Windings. In the case of a step-up transformer, the primary winding consists of relatively large copper wire because it must accommodate relatively large currents. The secondary winding is constructed of very small gauge copper wire because it is intended to accommodate much less current. The very opposite relations as to gauge of copper wire used for the primary and for the secondary windings, respectively, in the case of a step-down transformer, hold true; namely, the primary winding ordinarily consists of relatively small gauge wire, while the secondary winding consists of relatively large gauge. Thus, in either instance, the primary versus the secondary winding should be easily identified.

f. Transformer losses. The design and construction of transformers are very complicated engineering problems. There are numerous factors which govern their efficiency of performance. By efficiency is meant the power (in terms of wattage) of the primary circuit as compared with the total wattage induced (that is, available) in the secondary circuit. Very efficient transformers function with no more than a 2 to 5 percent loss in output (that is, secondary wattage) as compared with input (that is, primary wattage). Losses may be described as: copper losses, Eddy-current losses, and hysteresis losses. Copper losses are manifested by the production of heat in the copper wires of the coils. These losses may be reduced to a minimum by using wire of large diameter (and therefore low resistance). The iron core, itself, constitutes a closed electrical circuit. There are, therefore, currents induced into the core. These are called eddy-currents. They, too, are manifested by the production of heat. Eddy-currents are kept below costly values by constructing the transformer core of laminated iron rather than of a solid piece of iron. The third factor, hysteresis, is lag of magnetism behind the magnetizing current, in the core. Hysteresis losses are reduced by the use of silicon

steel in construction of the core. All of these factors are affected by proportionalities as regards the number of windings of the copper wire as compared with the bulk of the iron core; the spacing of the windings of the copper wire; the design of the core and the spacing between it and the copper windings, etc. Most transformers designed for functioning with X-ray apparatus are of relatively low efficiency. With some, losses may amount to 50 or even 60 percent. What is even more important is the fact that their performance varies with different loads. This may be accounted for on the basis of variations in wave form of the secondary currents. With one current load of milliamperage, the wave form may closely approximate a sine wave; with another, usually a higher load, it may be greatly distorted. As a result, even though potentials in terms of kilovoltage be duplicated, there may be marked differences in roentgenographic effect for the same exposure in terms of milliampere-seconds. Furthermore, it must be realized that there will occur a drop in the potential (in particular, the induced voltage of a step-up transformer), as the load is increased in the secondary circuit. For further details on this, reference to the section on calibrations is suggested.

29. AUTOTRANSFORMER. a. General. In an X-ray unit, an autotransformer is a device designed to select the voltage of an incoming alternating-current for application to the primary of the step-up transformer. It is constructed of a single winding or series of loops of large gauge copper wire wound about an iron core, in a manner comparable to that of an iron core electromagnet. It differs from an ordinary transformer in that it contains a single winding and this winding provides at least an electromagnetic linkage for two or more independent circuits. On one side of it, related to the secondary circuit of the autotransformer, there are a number of leads extending from one or another winding in the coil. These provide for connecting into the secondary circuit, a variable number of turns. Depending upon the number of turns utilized in the secondary circuit, as compared with the total number of turns contained in the autotransformer, and the voltage applied, there is accomplished a selection of voltage for application to the primary winding of the step-up transformer. For this reason, the functioning of the secondary circuit of the autotransformer has invoked description of it as a "volt selector." Similar leads to individual windings may be provided for the primary circuit of the autotransformer. With such, a variable number of turns or winding may be utilized in the primary circuit. Thereby, depending upon the number of turns included in the primary circuit as compared with the total number of turns contained in the autotransformer, there can be accomplished a control of the voltage across the entire number of windings. Such control of primary voltage is described as line voltage compensation. Thus, the primary circuit of the autotransformer may function as a *line voltage compensator*.

b. Electrical connections. The primary circuit of the autotransformer is connected into the incoming line; its main functioning secondary circuit is connected with the primary winding of the high tension transformer. Thus, the secondary winding of the autotransformer is a part of the primary circuit of the high tension transformer. Additional secondary connections may be provided for pilot lights and other circuits.

c. Major and minor controls. The simplest design of an autotransformer includes a single set of leads to its windings. These loads may extend to successive turns or to a number of them, having one, two or more turns between the leads. The greater the number of turns between the leads, the greater will be the difference in voltages pertaining to them. In order to provide steps of considerable voltage variation and therefore, more minute adjustment, there may be two sets of leads, one set having many turns between each lead; the other having few turns between leads. The control concerned with the leads having many turns between them is described as the "major control"; that having few turns between the leads is described as the "minor control." The terms, major and minor controls, pertain especially to the variable contact arrangements in the secondary circuit of the autotransformer but this same variation of control may be provided in its primary circuit for line voltage compensation.

d. Functioning. As in the case of ordinary transformers, the autotransformer is essentially concerned with voltage. If there be no means of variation in the number of leads utilized in its primary (that is, no controls for line voltage compensation) its functioning is essentially that of a variable step-down transformer. If line voltage compensation is provided, it may be possible to build up a voltage in excess of the line voltage and in this way, it may function as a variable step-up transformer. As compared with the functioning of an ordinary transformer, that of an autotransformer might best be understood by consideration of three voltages; voltage of the incoming line, that across all windings of the autotransformer and that of its secondary circuit. Referring to figure 17, when control "*A*" is adjusted as indicated so that less turns are utilized in the primary b-c than are incorporated in the entire transformer d-c, the voltage across the entire number of turns, as indicated on the voltmeter "V_2," will be greater than the voltage recorded on voltmeter "V_1," (that is, the line voltage), and the relationship will be approximately in proportion consistent with the number of turns utilized in each instance. If the controls "*B*" and "*C*" should be adjusted so as to utilize the entire number of turns for the autotransformer; then, except for minimal

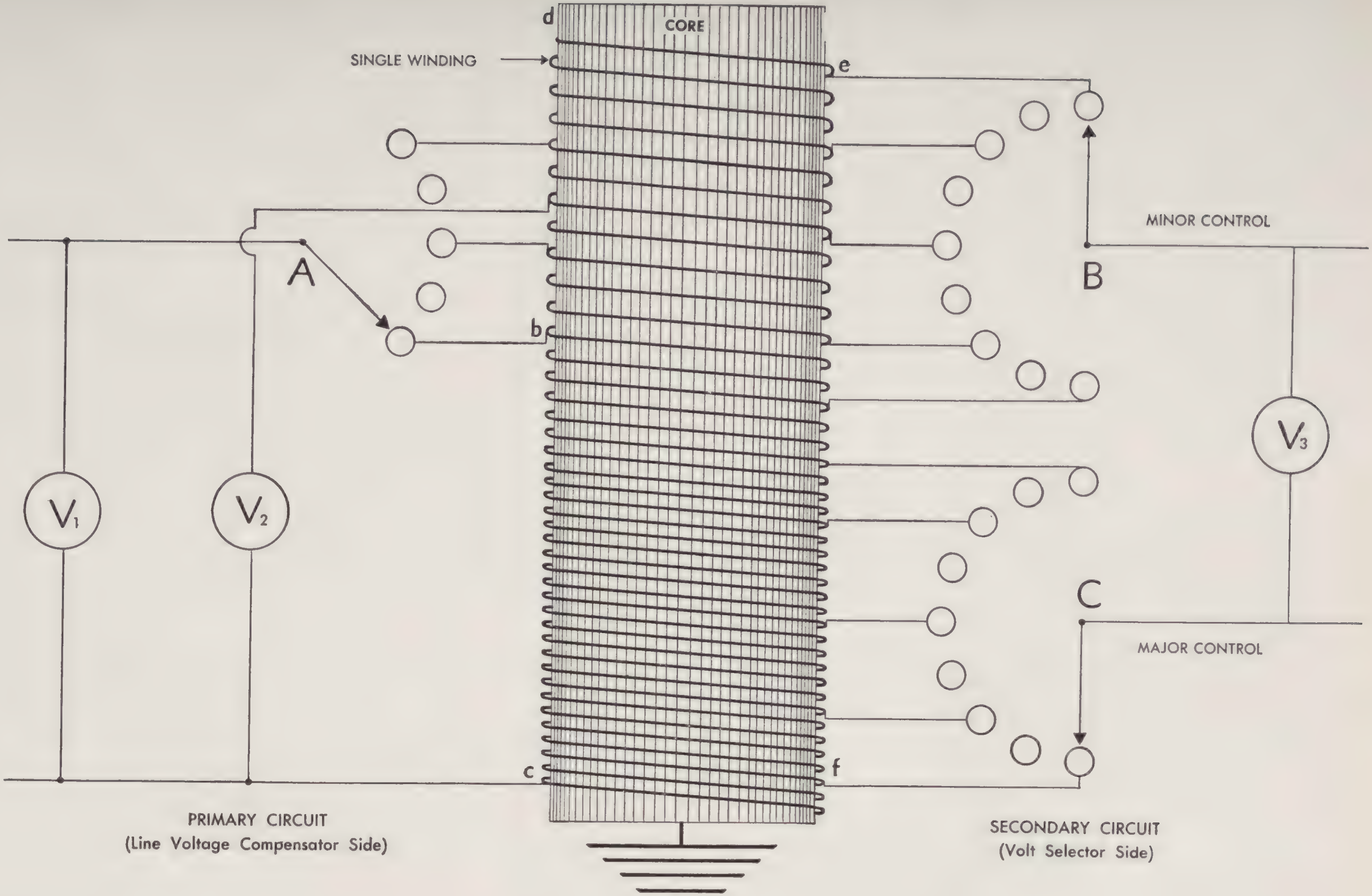


Figure 17. Autotransformer.

transformer losses, the end result would be a step-up in voltage. Adjustments of controls "*B*" and "*C*" whereby fewer turns are utilized in the secondary e-f, will result in reductions in voltage for the secondary as indicated on voltmeter "V_3." Thus, variations in control "*A*" will affect the voltages indicated in voltmeter "V_2" and voltmeter "V_3"; whereas, variations in controls "*B*" and "*C*" will not produce any change in the voltage indication of voltmeter "V_1" or voltmeter "V_2" though they will produce variations of voltage as indicated in voltmeter "V_3."

e. Current and voltage relationships. Figure 18 represents three different arrangements of the autotransformer, each consisting of 100 turns of wire. In figure 18A, if 100 volts are applied across 50 turns of the coil at *BC*, then the voltage per turn will be 2 volts. Hence, the voltage across *AC* is 200 volts. If the secondary winding *AC* is connected to a load where 5 amperes are drawn, then the current drawn in the primary circuit will be 10 amperes in accordance with the Power Law relationships. The current in windings *AB* and *BC* will flow in the directions indicated. In figure 18B, windings *BC* represent the secondary. If the voltage across the secondary *BC* is 50 volts and the load draws 20 amperes, then 10 amperes will flow by conduction in *AB* and 10 amperes will flow through *BC* by transformation (that is, induced current) in the directions indicated. In figure 18C, the secondary voltage is 80 volts. If the load draws 12.5 amperes, then 10 amperes will flow by conduction through *AB* and 2.5 amperes will flow through *BC* by transformation in the directions indicated. The transformers represented are diagrammatic and would not constitute an efficient arrangement under actual application. With autotransformers it is impractical to attempt alterations of voltage to the extent that secondary voltages be in excess of 25 percent, plus or minus, of the primary voltage. When the autotransformer is used in a step-down capacity most of the current in the secondary circuit comes directly from the supply by conduction; the remainder of the current is obtained by transformer action (that is, electromagnetic induction).

30. GROUNDS. a. General. When a point in an electric circuit is connected to earth through a low resistance path, that point in the circuit is said to be "grounded." The electrical difference of potential between the earth and the "grounded" point is zero, or practically so, depending upon whether the "ground" is good or poor. A good ground means that the resistance of the path is very low (that is, in the order of 0.1 ohm); whereas, a poor ground has higher resistance. The path to ground must be as low in resistance as possible.

b. Types of grounds. Several different means of grounding roentgen-ray machines are employed. The low resistance path should be a copper wire, not less than two sizes smaller than that of the correct carrying leads, plus a continuous metallic system which is, at least in part, buried beneath the surface of the ground. For example, the Army Field X-ray Unit, when used in the field should be grounded through a rod or pipe (copper, brass, or galvanized iron about ½ inch or greater diameter) driven into wet soil to a depth of 2 feet or more. If pipes or rods are not available, a flat sheet of metal of equivalent surface area might be used. Resistance to this type of ground connection can be

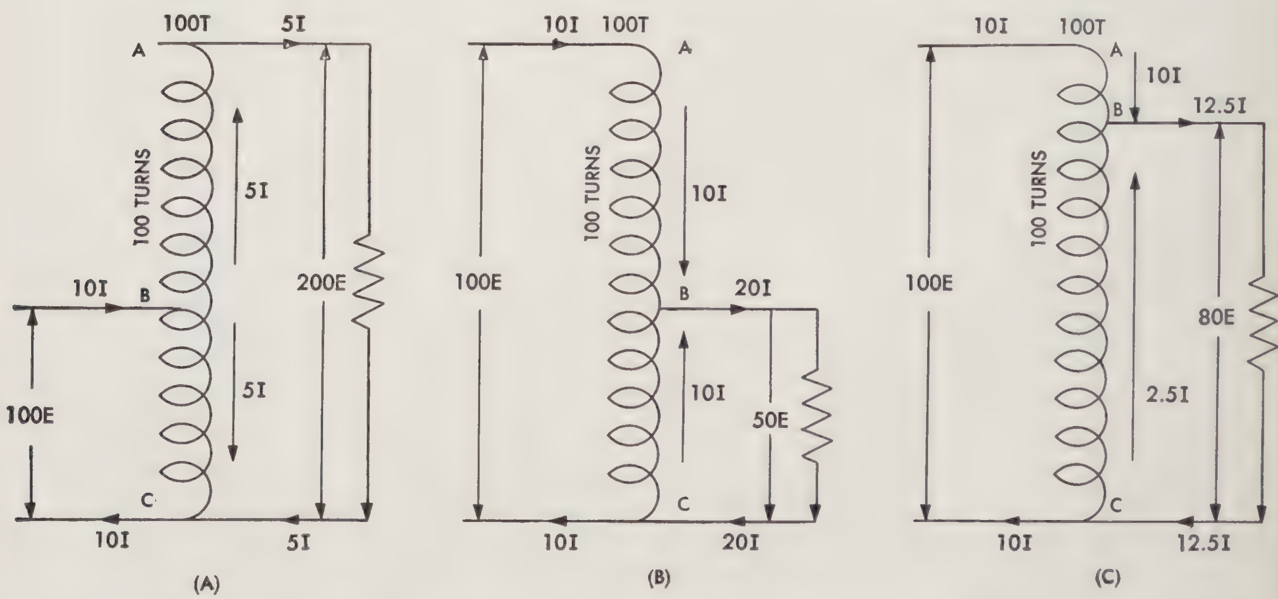


Figure 18. Current and voltage relationships of autotransformer.

reduced further by soaking the ground with water. For inside installations, ground wires may be connected to water pipes or electrical conduits. Water pipes are perferable. Regardless of the type of ground, contact junctions between parts of the system must be clean and firm. Soldered junctions have minimum resistance and are preferable. Spring clips may be used, provided the clips are large and are equipped with strong springs. Paint, oil, and other insulating materials should be removed thoroughly from the contact surfaces.

c. Purpose. The primary purpose of grounds in roentgen ray machines is to protect patients, technicians, and roentgenologists from electrical shock. Ordinarily, the human body has the same electrical potential as the earth. No current flows between them. Therefore, if contact is made with grounded portions of a machine, no current would flow through the body and there would be no electrical shock. Conduits, metal cases, or frames of equipment (panel cabinet, roentgenographic table, tubestand, (etc.) *must* be grounded (or isolated) so that, if by accident any of the circuit wires should touch any of the metal inclosures, no dangerous current would be passed to a person who might be in contact. Grounds also permit machines to be manufactured with less insulation than would be required otherwise. A good ground will permit sufficient current to open a circuit breaker, or burn a fuse, and thus clear the fault. Without this safety factor, high voltages might build up on metallic parts and thus become electrical hazards.

d. Application of ground to community power systems. Community power systems, whether single or three-phase, usually have a neutral (ground) wire present. Where a single-phase system consists of three wires, one of the wires, usually the middle one, is grounded. If connections be made to either of the outside wires and the middle wire (ground wire), then the useful voltage will be one-half of the original voltage. This wiring arrangement is usually utilized in homes, offices, or hospital wards here in the United States. There is one "hot" wire and a neutral or ground. When 220 voltages are commonly connected into the building on three-phase systems, the supply may be four-wire where three wires are "hot" and one is neutral. When the "hot" wires are connected to the site of consumption, the plumbing system of the building provides the ground or neutral. By utilizing any one or two "hot" wires plus a grounded wire, single-phase current may be utilized. It is important to realize that if two "hot" wires of a three-phase system are utilized, single-phase will result, but the absence of a ground wire will make the system dangerous in the event of short-circuit.

e. Application of grounding to X-ray equipment. The electrical circuit of an X-ray machine makes provision for grounding various portions of unit. The X-ray transformer need not be grounded in order to function. It must be emphasized that in modern equipment, since the milliammeter is connected at the midpoint of the secondary, a ground is required. The core of the filament, high tension and autotransformer are grounded to the case or framework. Under normal operating conditions, the housing and structural material of the unit acts as a "ground." In the event of short-circuit, it will be a poor "ground" and injury might occur to individuals who may make contact with the equipment. In order to avoid this possibility, a wire of suitable size connects all the "grounded" portions of the unit to a proper ground. This wire is identified as the ground wire and should be connected to a good ground such as a water pipe. Item No. 96085 and Item No. 96215, Field X-ray Units, are provided with a separate ground wire incorporated in the supply cable. It provides a general pathway for all the grounded portions of the unit. If the ground is not connected, the units will still function as the framework acts as a ground but this procedure is subject to danger and the wire should always be connected. Item No. 96060, Gas-Electric Generator, may be grounded by connecting to a water pipe or in the field by use of the brass stake supplied. This will ground the frame of the generator and the ground wire of either Item No. 96085 or Item No. 96215 may be connected to it. Item No. 96115, X-ray Field Processing Unit, should always be grounded. The frame may be connected to a suitable ground by use of a separate wire. Care must be taken to provide for good contact. Item No. 96055, X-ray Field Drying and Loading Bin, should also be grounded by connecting any portion of the frame to ground. Item No. 96145, X-ray Field Table Unit, when operated in the field, should also be grounded.

SECTION II. ROENTGEN-RAY TUBES

31. GENERAL. The X-ray tube might be considered to be the essential performer as compared with all other components of an X-ray machine. Its performance is dependent upon a gap between two terminals contained in a vacuum; one from which electrons are driven; the other, upon which they are bombarded. From the latter, there is emanated the X-radiation energy. For proper functioning, many characteristics are required. It is not enough that the X-ray tube merely provides a source of X-ray energy. It must provide this energy from as nearly a point source as possible, and yet, the design and construction of the tube must be such as to tolerate the enormous proportions of heat generated concurrently with the X-ray energy. X-ray tubes vary markedly, both with respect to the point source feature mentioned and with respect to tolerances which govern their application for various types of

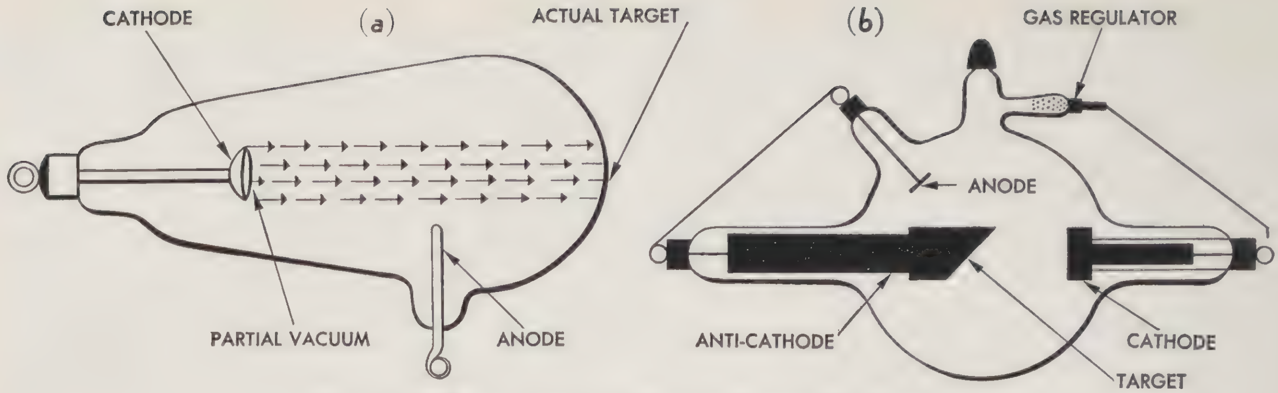


Figure 19. X-ray tubes: (a) Roentgen's tube, (b) Gas tube.

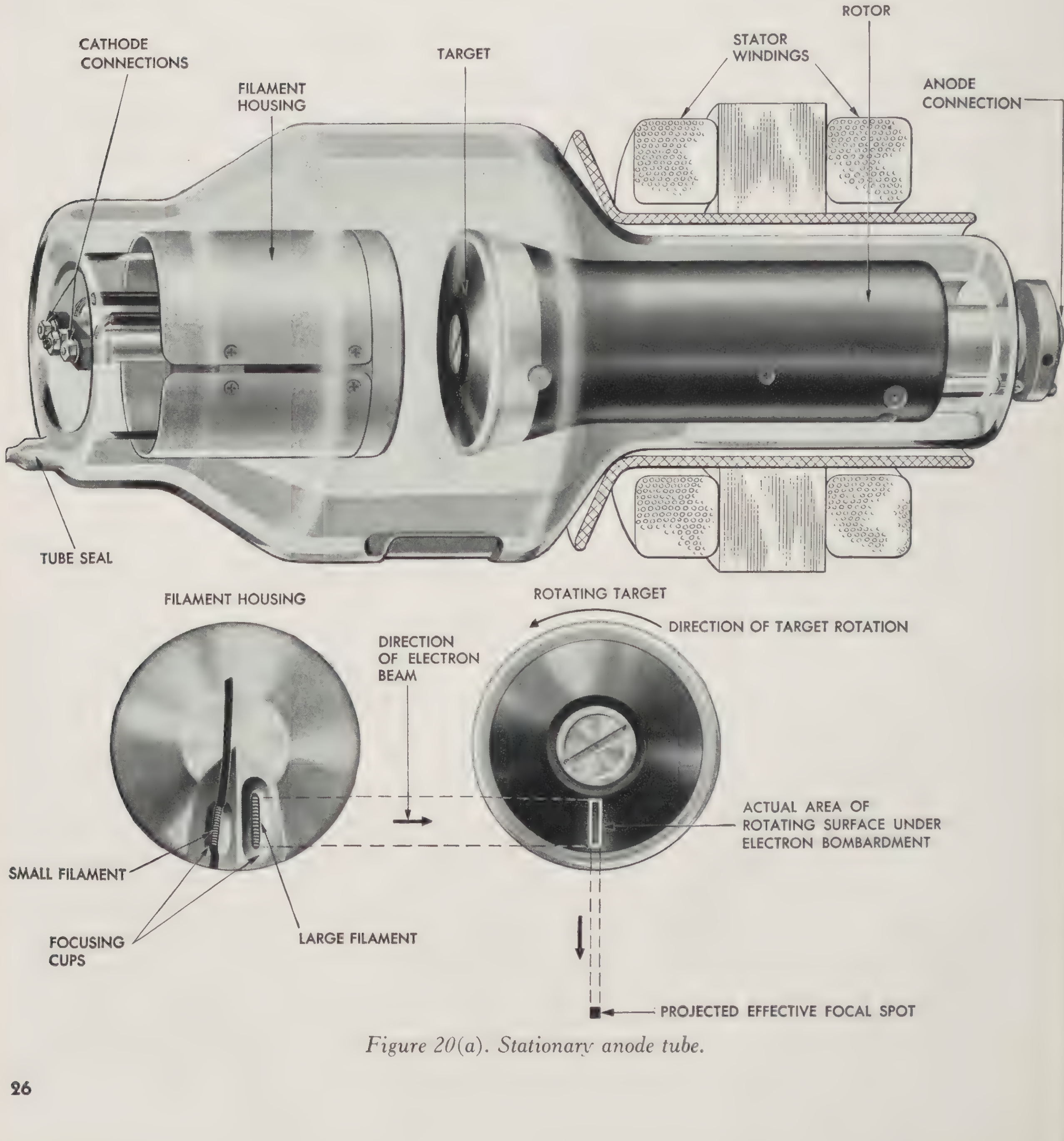


Figure 20(a). Stationary anode tube.

roentgenography and roentgenotherapy. Most outstanding developments have been made in the design and construction of X-ray tubes. These began soon after Roentgen's discovery and they have continued to date. In particular, the refinements have been along three general lines: decrease in tube size; increase in tube capacity (milliamperage and kilovoltage); and increased electrical radiation safety. With proper handling, X-ray tubes, like light bulbs, endure prolonged usage, though with heedlessness as to their tolerances they may be destroyed within a few seconds.

32. GAS TUBES. The first tubes were large glass bulbs (fig. 19a and b), partially evacuated and containing two or three sealed-in metallic electrodes (cathode and anode; later, also, an anticathode). They were called "gas" tubes. Several thousand volts of electrical potential ionized (broke up into negative and positive charges) the residual gas and made it a conductor of electricity. These electrified particles attained high energies of motion. Some collided with the anticathode and roentgen rays were emitted at the site of collision. The magnitude of current which flowed through the "gas" tube depended upon the gas pressure in the tube and the applied voltage. Increased voltage resulted in increased tube current. Variations of the gas pressure was a disturbing factor. In order to overcome the inconstant functioning of these tubes, the hot cathode or Coolidge type of modern tube was developed.

33. HOT CATHODE TUBES. a. General. Hot cathode tubes contain two metallic electrodes, a cathode, and an anode. (See fig. 20a.) All gases, so far as is possible, are removed. The method consists of a small coil of tungsten wire, called the filament, supported by two heavy copper wires. These wires serve also to carry heating current to and from the filament. Most filaments are about one centimeter long and from 0.2 to 0.3 centimeters in diameter. The filament becomes a source of electrons when heated to incandescence. The anode is a solid rod of copper and molybdenum, sealed into the opposite end of the tube. The inner end of the anode is opposite the filament and fixed a few centimeters from it. A small block of tungsten is "buried" in the anode directly opposite the filament. This tungsten block is called the target of the tube. It serves as a "stop" for the electrons as they stream across the tube. Tungsten is used because it has a high melting temperature (3370° C.).

b. Focal spot. Most electrons bombard the target over a small area near its center. This area is called the "actual focal spot" of the tube. (See fig. 21.) The actual focal spot has an area nearly equal in size to the over-all dimensions of the filament. For reasons to be discussed later, the smallest possible focal spot size is desirable. Shields are, therefore, built around the filament, whereby the electron beam is concentrated to a small cross-sectional area. Whenever, a high speed electron strikes the target, its energy is transformed into radiant energy and roentgen rays are emitted from the point of collision. Those rays which emanate from the focal spot are called the "primary rays" or primary radiation beam. A few electrons hit the anode elsewhere. Rays from such collisions are called "stray radiation." Stray radiations serve no useful purpose. They are undesirable and are therefore eliminated by placing heavy shields around the tube.

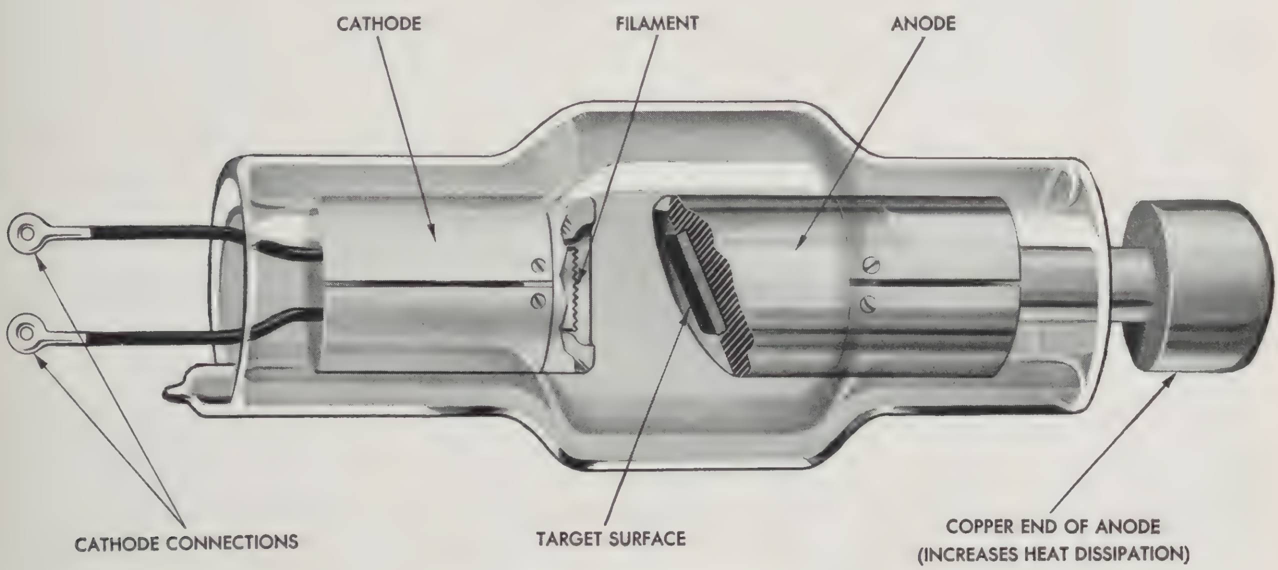


Figure 20(b). Rotating anode tube.

c. Double focus tubes. Certain types of roentgen-ray tubes contain two filaments. They therefore have two focal spots. They are called double focus tubes. One spot only is used at any one time. In a double focus tube the filaments are supported by three copper wires. One of these three wires serves both filaments.

d. Effective projected focal spot. The area of the target hit by the electrons is the actual size of the focal spot. This area is slightly larger than the filament itself because the face of the target is inclined slightly with respect to the axis of the tube. The inclination of the target face is selected so that a view of the focal spot in a direction perpendicular to the axis of the tube gives the impression of a square area for the focal spot. This square area is called the effective projected focal spot. It usually measures from 1 to 5.2 millimeters square.

e. Cooling of the target. Electrons, activated in the hot cathode and accelerated by the tube voltage, move from cathode to anode at speeds ranging from 30,000 to 100,000 kilometers per second. When the electrons hit the target, 2 percent or less of the energy (depending upon the applied voltage) is transformed to roentgen rays. The other 98 percent is converted into heat. The target of an X-ray tube, operated at 50,000 volts and 100 milliamperes of current, has produced in it, about 1,200 calories of heat, each second. A tungsten target, weighing approximately 15 grams and losing no heat, will

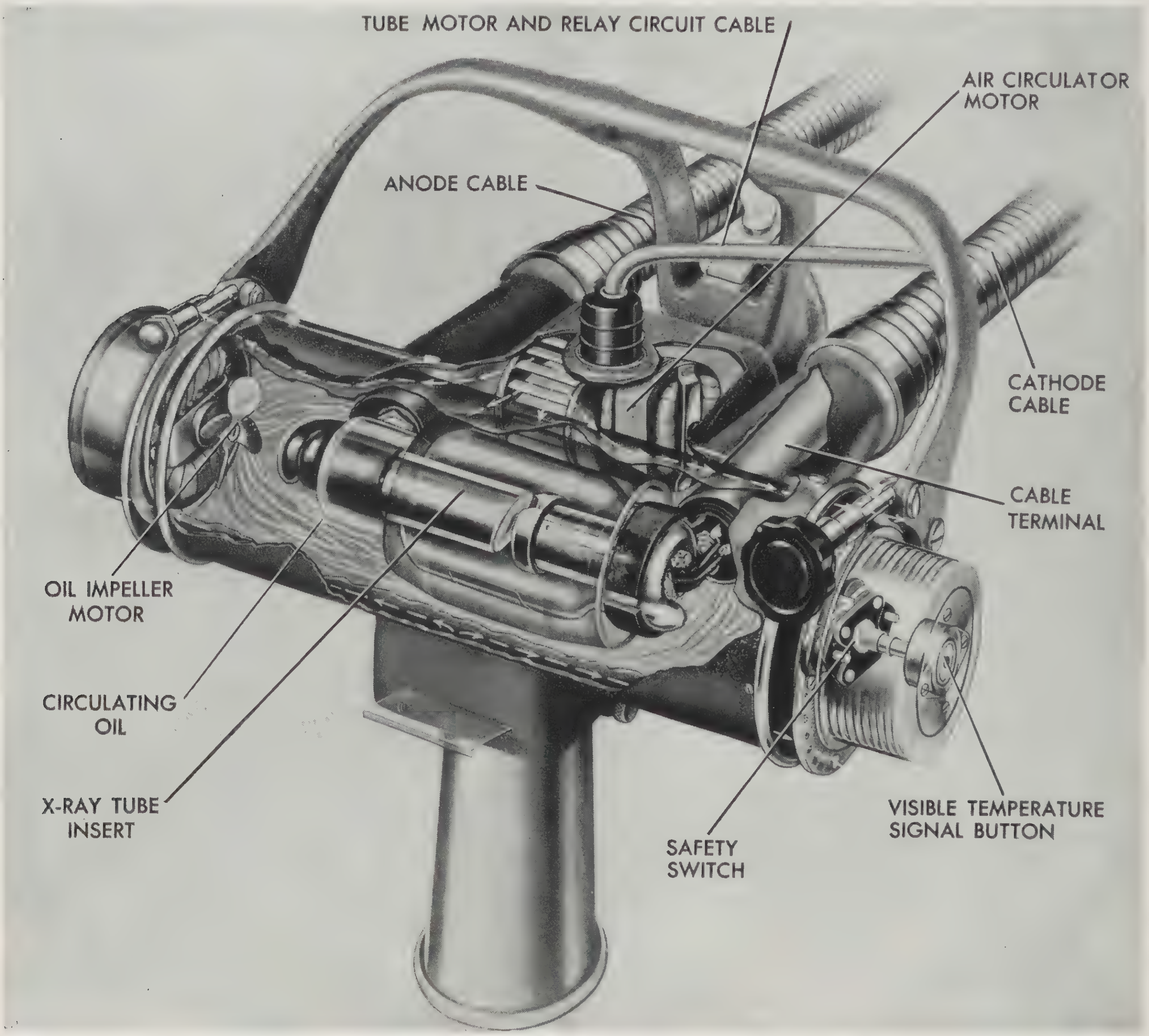


Figure 20(c). Tube for Item 96085.

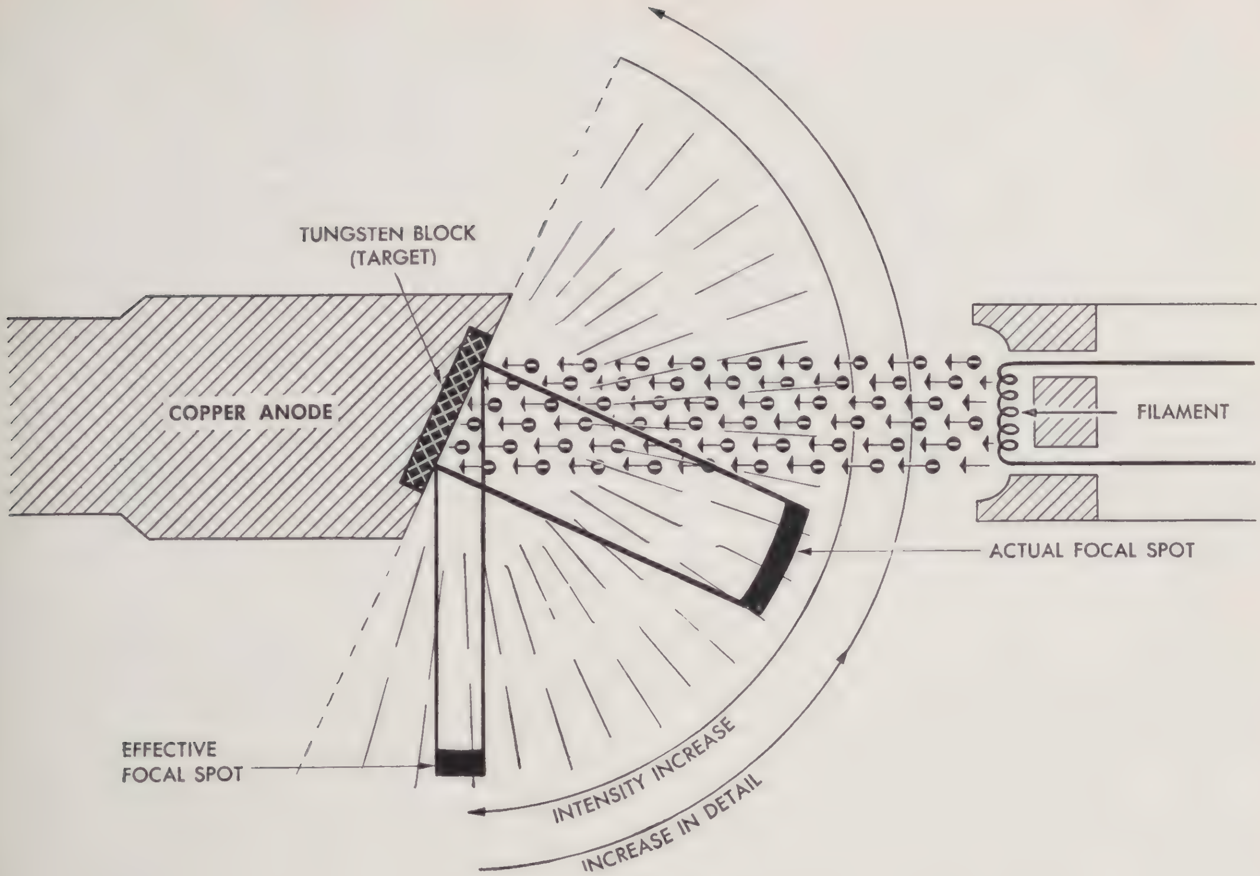


Figure 21. Focal spot.

undergo a temperature of 2400° C, in 1 second. Enough heat is generated to actually melt the target in 2 seconds. It is necessary that some means of cooling be provided, if the target is to be preserved. Tubes are classified according to types of cooling. There are air-cooled, liquid cooled, and combined air and liquid cooled tubes. (See fig. 20c.) Air-cooled tubes lose heat by conduction to the glass bulb; thence, to the air of the room. Dissipation of heat is accelerated by radiators attached to the anode outside of the tube wall. Liquid cooled tubes are immersed in oil or have oil or water circulating in or about the anode stem. The most recent development toward greater heat capacity is the rotating anode type of the tube. (See fig. 20b.) In these, the anode is the rotor of an induction motor. It rotates at high speed when the tube is turned "on," and stops quickly when the tube is "off." The anode is a disk about 3 inches in diameter. The filament is set off center so that the electron beam hits this disk near its edge. At any instant, the focal spot is a small rectangular area near the edge of the disk, but the total heat is produced over a bandlike distribution, covering about 1 centimeter in width and extending along the periphery of the disk. Thus, heat is produced and stored in a much larger mass of tungsten, thereby maintaining temperature rises within safe limits.

34. ROENTGEN RAY TUBE CAPACITY. a. General. X-ray tubes are rated in terms of kilovoltage, milliamperage, and time of exposure values, depending upon the type of rectification employed, cooling method and the focal spot size. The ability of the tube to sustain energy loads is governed by the thermal capacity of the anode, the over-all thermal storage capacity of the tube and the heat dissipation rate. The characteristics of each tube and data relative to its capacity for any exposure are published by the manufacturer. (See fig. 22.) Strict adherence to the tube rating chart will assist materially in obtaining the maximum operating efficiency and will prolong the usefulness of the tube. Frequently, the question arises as to the "life" of an X-ray tube. Carelessness in operation of, and exceeding the capacity of a tube during an exposure, even to the extent of a mere overtime of a fraction of a second, may result in its destruction.

b. Kilovoltage capacity. The kilovoltage capacity of the X-ray tube is predetermined by the manufacturer depending upon the use for which it is intended—roentgenography, roentgenoscopy, and therapy. The internal dimensions of the cathode and anode—the distance of the filament from the target are a function of the maximum voltage that may be impressed across the tube. In comparing a therapy tube with a diagnostic tube, it will be noted that

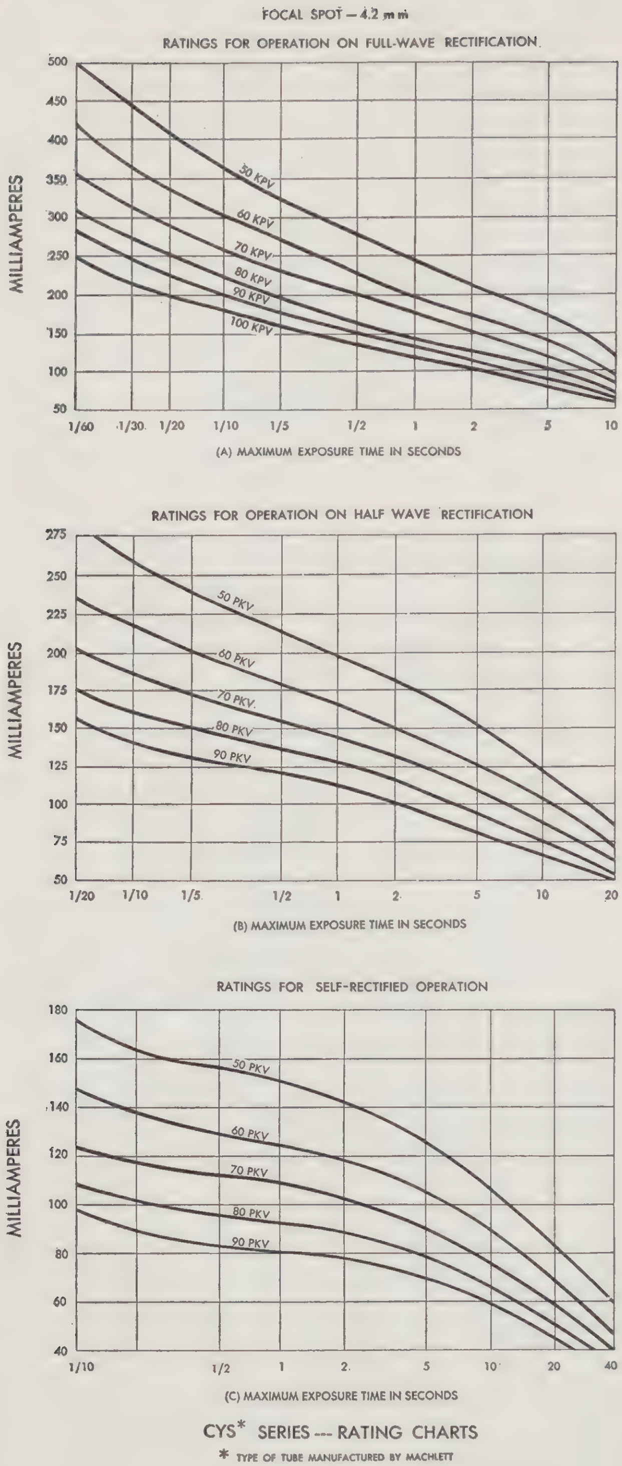


Figure 22. Rating chart.

there are appreciable differences in the cathode-anode spacings. For roentgenography, where the acceptable range for diagnostic work is from 30 to 90 kvp (in some instances, as high as 125 kvp), the tubes are constructed with these kilovoltage ranges in mind. A tube designed for roentgenography may be utilized for roentgenoscopy, since the maximum potential in general practice rarely exceeds 85 kvp. For light therapy, 90 to 140 kvp is employed, while for medium therapy 140 to 220 kvp is used. For deep therapy, 220 kvp is usually considered as the minimum value. If the kvp capacity is exceeded, tube puncture may occur at the bulb, usually in the cathode portion facing the anode. High electrical strains are created over the glass and puncture may occur at points of structural weakness. Since practically all modern, shockproof-rayproof diagnostic tubes are designed to tolerate 90 to 100 kvp, this type of tube failure has been materially reduced. Unpredictable line surges and variation of the potential of the high tension transformer is usually the cause of tube puncture. Maximum kvp ratings are established on the assumption that the tube is operated with a transformer with a center-grounded secondary. On full-wave, four-valve, and half-wave two-valve rectified circuits, for most diagnostic units, the maximum voltage on each cable must not exceed 50 kvp to ground. When the tube is operated on single-valve or self-rectified circuits, allowances must be made for inverse voltage (that is, the useful voltage must be reduced to where the above mentioned value represents half of the *inverse*).

c. Milliamperage capacity. The maximum permissible energy load for a single exposure of a given time interval is, in a great measure, determined by the size of the actual focal spot under electron bombardment (par. 33b) and the type of machine circuit. (See par. 42.) Figure 22, indicates the maximum permissible load that may be expected, if kvp and ma energies used are lower than those shown in the rating charts. One of the prime requisites of an X-ray technician is that he must be capable of interpreting data and ratings on the tube charts. The proper method to secure the maximum permissible exposure time for a tube would be to refer to the manufacturer's rating chart. These may vary from one another, depending upon whether the kvp and ma are plotted as ordinates or abscissae. For an example, suppose a tube has a 4.2 mm focal spot and is operated at 90 kvp for 200 ma on a full-wave rectified circuit. Referring to the chart in figure 22, follow the vertical column of ma values until 200 ma is reached. Trace this line horizontally until it intersects the 90 kvp curve. Now, follow down vertically from the intersecting point to the base line, and it will be readily seen that the maximum time of exposure is $\frac{1}{10}$ second. In general, it may be stated that the maximum permissible energy that can be sustained by a specified tube is proportionate to the size of the focal spot.

d. Effect of rectification on tube capacity. The type of rectification employed is an important consideration in determining tube capacity. In figure 22, the rating chart for a 4.2-mm tube was used. Chart "A" applies only to the tube operated on a full-wave rectified circuit, while charts "B" and "C" indicate

the permissible exposures for half-wave and self-rectification respectively. It will be noted that on full-wave at 80 kvp for 100 ma, the tube may be operated for 5 seconds; whereas, for half-wave the exposure time is limited to 3 seconds and with self-rectification, to $\frac{1}{5}$ second. It should be clear that for the short exposure time on self-rectified circuits as compared with full-wave and half-wave there is a greater strain of the inverse voltage on the tube. This condition becomes more pronounced when the temperature of the target is increased following electron bombardment. As explained in paragraph 44, the valve serves to suppress the inverse voltage, even though the temperature of the target is increased. Therefore, in self-rectified circuits, the X-ray tube is subjected to great electrical and heat loads and hence has a lower capacity than with half or full-wave circuits. To understand the difference between half-wave and full-wave, it must be realized that on half-wave the milliammeter is recording only half the time, since only half of the impulses flow through the circuit. The instrument, however, due to the inertia, records only a steady mean, which in this case is approximately one-third of the peak value attained by the current during any one impulse. The *actual* current passed through the tube may be as high as 300 ma even though the meter records only 100 ma. For full-wave rectification, since all of the current is rectified and passes through the tube, the moving parts of the milliammeter are activated more frequently. Therefore, the mean current recorded by the milliammeter is nearer the actual peak value, and it has been determined that the peak is approximately one and one-half times the meter reading. Hence, the *actual* tube current would be 150 ma; whereas, the meter would be reading 100 ma. In the above example, the total power delivered, irrespective of the type of rectification is the same. For half-wave, more electrons for a given meter reading strike the focal spot than for full-wave and, consequently, the temperature of the focal spot approaches its maximum point more rapidly. On full-wave, the current is passed in smaller amounts, but more frequently, (permitting the focal spot to tolerate a greater load and allowing a greater quantity of the accumulated heat to be conducted away from the target). The type of rectification, therefore, is an important factor to be considered in connection with maximum energy loads permissible for a single exposure.

e. Kilowatt rating. A method of determining the approximate milliamperage capacity of a tube with a given focal spot is based upon the ability of one square millimeter of tungsten to sustain 200 watts per second or 300 watts for $\frac{1}{3}$ second. This method is designated as the kilowatt rating and is of value, if a rating chart is not available. Some X-ray tubes may be identified as 2, 4, 6, or 10 kw (Philips). The 2 kw tube, for example, has a projected effective focal spot of 1.7 mm. The kilowatt rating and, hence, the permissible kvp and ma-sec. for 1 second may be determined, if the projected effective focal spot (*PEFS*) is known, by reference to the following formula:

$$Kw \text{ rating} = \frac{(PEFS^2 \times 3\frac{1}{2}) \times 200}{1000}$$

where $PEFS^2$ = the dimensions of the projected focal spot squared, $3\frac{1}{2}$ is a constant value, which is used to convert the size of the *PEFS* into the actual focal spot under bombardment, 200 is the wattage sustained by 1 square millimeter of actual focal spot and 1000 is used to convert watts to kw solving:

$$Kw \text{ rating} = \frac{1.7 \times 1.7 \times 3.5 \times 200}{1000} = 2.02 \text{ or } 2\ kw$$

Thus, a tube having a 1.7 mm effective focal spot and a target inclination of 19° may be identified as 2 *kw*. If the tube is operated at 80 kvp for 1 second, the maximum milliamperage for a 2 *kw* tube can be determined:

$$P = E \times I$$

Where P equals power available to the tube, E is equal to root mean square voltage and I is equal to average current, converting 80 kvp to rms voltage.

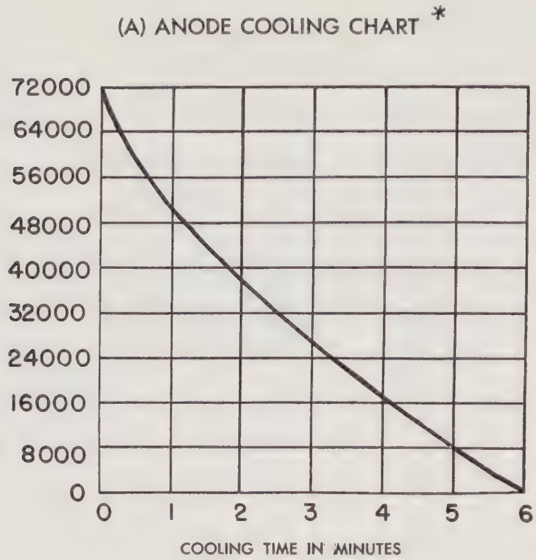
$$80{,}000 \text{ peak volts} \times .707 = 56{,}560 \text{ volts}$$

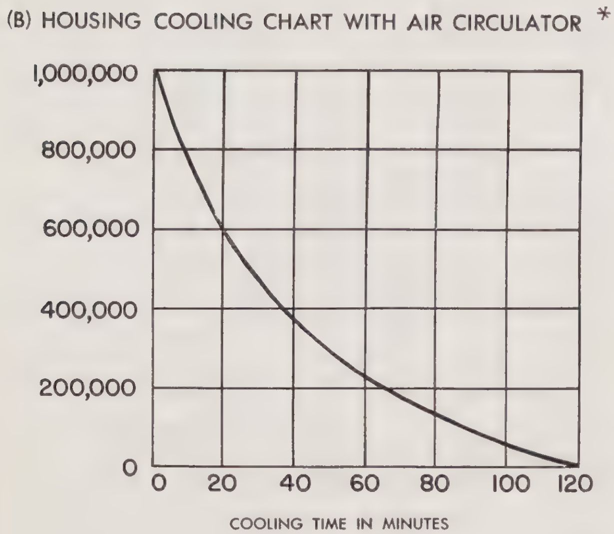
$$I = \frac{P}{E} = \frac{2000}{56{,}560} = .035 \text{ or } 35 \text{ ma}$$

Hence, a 2 kw tube, lacking a rating chart may be operated at 80 kvp for 1 second at 35 ma.

f. Anode thermal capacity. When exposures are made in rapid succession, heat is stored temporarily in the anode, and then transferred into the surrounding volume of oil and metal parts. Figure 23a, is an example of an anode cooling chart. Heat produced in the X-ray tube is expressed in terms of arbitrary units called Heat Units (H. U.) and is equal to the product of kvp x ma-sec, (based upon Joule's Law: par. 18). When the heat storage capacity of the anode of an X-ray tube is 75,000 H. U., a series of exposures may be made safely in rapid succession, until the capacity is reached, at which time the anode must be allowed to cool sufficiently, before any other exposures are attempted.

g. Thermal storage capacity and heat dissipation rate. In addition to the anode thermal capacity, consideration must be given to the over-all thermal storage capacity and heat dissipation rate. The over-all thermal storage capacity of a tube varies, depending upon the size and rate of heat dissipation of the anode. Various cooling methods are used to cool the anode. (See par. 33e.) The thermal storage capacity of X-ray tubes may vary from 100,000 to 300,000 H. U. for stationary anode tubes to as high as 250,000 H. U. per hour for rotating anode tubes. (See fig. 23b.) When the heat storage capacity has been fulfilled, then the rate of thermal dissipation per minute becomes the governing factor in calculating the maximum number of exposures that





* DATA PERTINENT TO "DYNAMAX" X-RAY TUBE MANUFACTURED BY MACHLETT

Figure 23. Cooling chart.

can be made safely in rapid succession during a given working period or for continuous operation (that is, as in induction station examinations). Suppose, for example, as in the case of chest photoroentgenograms, the technique requires an average exposure of 90 kvp 200 ma at $\frac{2}{10}$ second. To determine the heat units developed per exposure:

$$\begin{aligned} \text{H. U.} &= \text{kvp x ma-sec} \\ &= 90 \times 200 \times .2 = 3600 \\ \text{H. U.} &= 3600 \end{aligned}$$

If a tube has a heat dissipation rate of 8,000 H. U. per minute (Aeromax), then to determine how many exposures may be safely made at the above factors per minute for continuous operation, divide the H. U. developed per minute into the cooling rate, and solving:

$$8000/3600 = 2.2 \text{ or } 2 \text{ exposures per min.}$$

If the cooling rate is 25,000 H. U. per minute, as in the case of some rotating anode tubes (Dynamax) it is obvious that a greater number of exposures could be made for continuous operation. For example, if this tube is used and the same average exposure is made as above except that a stereoscopic view is made on each subject, it is possible to determine the number of men that can be examined per hour for continuous safe tube operation.

$$\text{H. U.} = 90 \times 200 \times .2 = 3600 \text{ for one exposure}$$

$$\text{For stereo} = 3600 \times 2 = 7200 \text{ H. U.}$$

$$\text{Permissible No. of exposure} = \frac{\text{tube cooling rate}}{\text{H. U. developed}}$$

$$= 25000 = 3.4 \text{ or } 3 \text{ per man exposed}$$

Hence, this type of tube, having a cooling rate of 25,000 H. U. per minute, would permit 3 men per minute or 180 men per hour to be examined at a continuous rate with a stereoscopic study of each. Even this type of tube may be destroyed where the operator, in the middle of the photoroentgen run, becomes overzealous permitting either more prolonged exposures to be made (that is, when dealing with unusual dimensions and the use of the grid) or more than the six exposures per minute (that is, three stereoscopic pairs). It is at this stage, where the tube is operating near capacity that what might seem an insignificant addition may result in destruction of the tube.

SECTION III. REQUIREMENTS FOR ROENTGEN-RAY PRODUCTION

35. PHYSICAL REQUIREMENTS. a. General. The physical requirements for the production of roentgen rays are essentially three in number: a source of corpuscular rays, (electrons), a means of setting them into rapid motion, and a means of slowing them down or stopping them. Roentgen ray machines provide these requirements. Thousands of dollars worth of electrical equipment is required. Only by diligent study of the machine and patient consideration of its limitations can the technician ever hope to master its usefulness.

b. Electron source. The electron source, or corpuscular ray requirements, of the modern X-ray machine is the hot filament of the X-ray tube. The tungsten filament (heated to incandescence) emits electrons. The process is called thermionic emission of electricity. Actually, thermionic electricity is not different from any other electricity.

c. Thermionic emission. At room temperatures, electrons are bound to atoms in the filament. At higher temperatures these bonds are loosened, and

many electrons become free, momentarily. Their freedom is short lived, unless some external force removes them from the filament. Otherwise, they recombine with the atoms. A weak electric field or small emf applied between filament and target (target of X-ray tube, plate of valve tube) will move some few electrons across the tube. (See fig. 24.) If the emf is increased, more and more electrons are drawn across the tube. Finally, at a specific filament temperature, the free electrons are drawn across as fast as they are produced. There is no opportunity for recombination. Thereafter, tube current remains constant, even though higher and higher emf's are applied. Under such conditions the tube current will have reached its maximum value for a given filament temperature. This value is the "saturation current." The lowest voltage which produces saturation current is called the "saturation voltage." Each value of filament temperature has a saturation tube current beyond which the applied voltage will no longer increase the tube current. However, as the temperature of the filament is increased, the tube current is also increased. Independence of the tube current and tube voltage is one of the most desirable characteristics of the modern X-ray tube. Low voltages and large currents; high voltages and small currents, or any combination of voltage and current, are possible.

36. CONTROLLED FACTORS IN OPERATING X-RAY MACHINE. Only three factors are controlled directly by the operator of a roentgen ray machine. They are: roentgen ray tube current (ma), roentgen ray tube kilovoltage (kvp) and time of roentgen ray emission (s). The essential circuits are divided, therefore, into three groups, each of which is designed to regulate one of the above factors. There are other circuits, which are less essential. They are called auxiliary circuits. They are related to the roentgen ray machine in much the same manner that horns are related to automobiles—nice to have but not necessary.

37. CIRCUIT POTENTIALS. Any conductor in contact with the earth, either directly or by means of a low resistance wire, is said to be "ground" at the point of contact. (See par. 30.) The circuits of a roentgen-ray machine may be at low or high potentials with respect to ground potential. Wires and instruments on the low side do not differ from ground potential by more than 110 or 220 volts, while parts at high potentials may be several thousand volts away from ground potential. The fullest measure of protection against electrical shock and burns is insured if the technician thoroughly acquaints himself with these considerations. (See table VI, app. V.)

38. TUBE FILAMENT REGULATING CIRCUIT (fig. 25). The current which flows through the roentgen tube, when voltage is applied is recorded by the milliammeter. Its magnitude depends upon filament temperatures. The greater the heating of the filament, the greater the flow of electrons from filament to target and the greater the intensity of X-ray production. The tube filament regulating circuit is a means of adjusting filament temperatures. The filament of the roentgen ray tube is heated electrically. Alternating current, 3 to 5 amperes and 3 to 10 volts, does this job. This power is taken from the main line, transformed by the filament transformer and applied to the tube filament. A variable resistor, or a choke coil, series connected into the primary of the filament transformer, is used to vary the primary current. The latter may be measured by a filament ammeter. The filament ammeter is a prereading meter; that is, tube currents are set by means of it, before roentgen rays are turned "on."

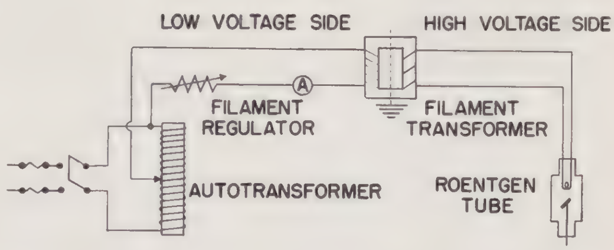


Figure 25. Filament circuit of a roentgen-ray machine.

39. TUBE KILOVOLTAGE REGULATING CIRCUIT (fig. 26). The cathode and anode of the roentgen tube may be connected directly, or indirectly (that is, through rectifiers) to the secondary coil of the high tension transformer. Thus, the secondary voltage of the transformer is also the approximate voltage between ends of the tube. The secondary voltage of the transformer is controlled by varying the voltage applied to its primary coil. Main power lines are usually connected to the primary side of an autotransformer. By regulation of the major and

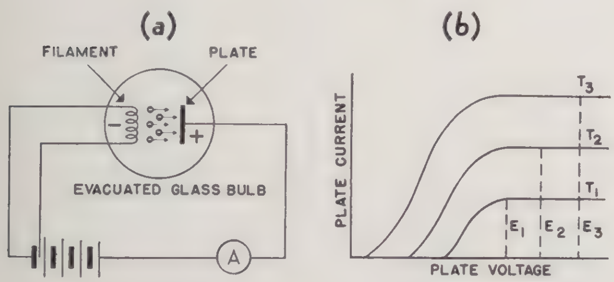


Figure 24(a). Thermionic emission of electricity. (b). Saturation voltage.

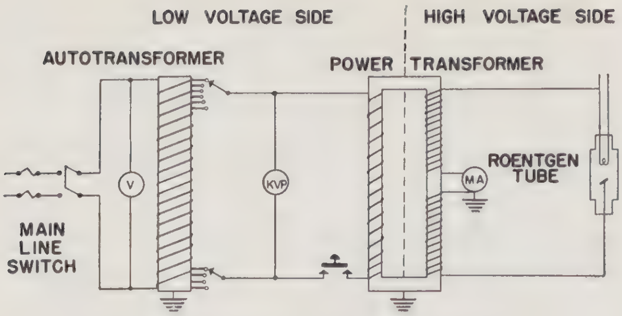


Figure 26. Tube kilovoltage control circuit —self-rectified.

minor settings of the latter, voltages are selected and applied to the primary coil of the high voltage transformer. The peak kilovolt meter, by arbitrary calibration of its scale, responds to primary coil voltage, but records calibrated values of secondary coil kilovoltage. The peak kilovolt meter is a pre-reading instrument.

40. TIMING CIRCUIT (fig. 27). The timing circuit determines total time that high voltage is applied to the roentgen tube, and thus, the time in which roentgen rays are emitted. High voltage is impressed on the tube only when current flows in the primary coil of the high voltage transformer. A switch, called the "contactor," and operated by means of an electromagnet, either by hand, foot, spring, clock, or electric clock, opens and closes the primary circuit of the high voltage transformer. The contactor, through its timer, thus controls the time of roentgen-ray production. This circuit is entirely independent of tube current and tube voltage circuits, but in some models of machines, its function is associated with certain safety devices.

41. AUXILIARY EQUIPMENT. Roentgen-ray machines are equipped with a number of "gadgets," which enable the technician to "run" the machine more easily and more safely, but, like headlights, speedometers, etc., of the automobile, they make driving a safe pleasure, though they do not contribute to the performance rate. Circuit breakers, fuses, and thermostats are used universally. They are safety devices, which protect wires from the damage of excessive electric currents. Insulation is preserved, and in some instances, melting of wires is prevented by them. Electric lights, low voltage type, serve as "pilot lights" to indicate what portions of the machine are energized. Thermostats open certain circuits and permit certain parts to cool to safe operating temperatures. Time relays provide sufficient time for filaments (roentgen ray and valve tubes) to attain maximum temperatures and for rotating anodes to acquire maximum speeds, before roentgen rays are turned "on."

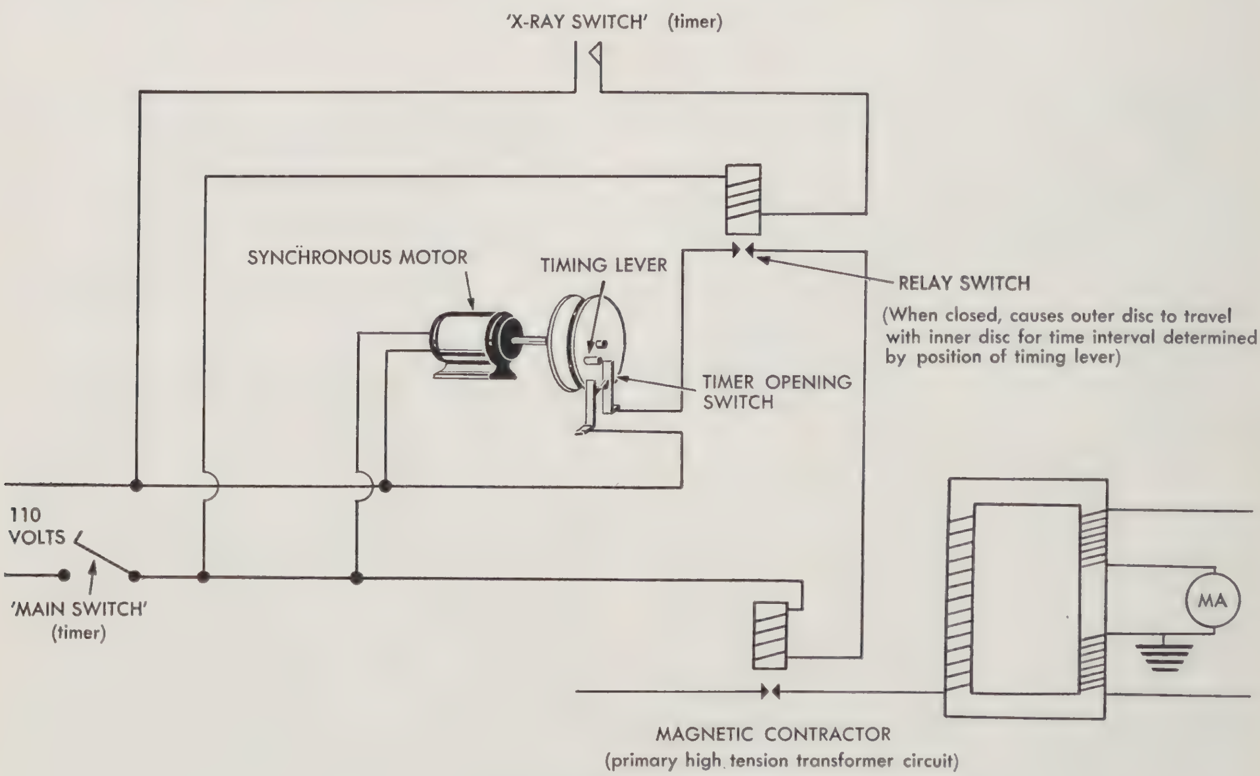


Figure 27. Timing circuit.

42. RECTIFICATION. By rectification an alternating-current and alternating voltage are changed to either a pulsating or direct-current and voltage. Instruments which produce rectification are called rectifiers. The X-ray tube itself may act as a rectifier; otherwise, two principal types of rectifiers are used in roentgen-ray machines. They are valve tubes and mechanical rectifiers. Some valve-tubes are called kenotrons.

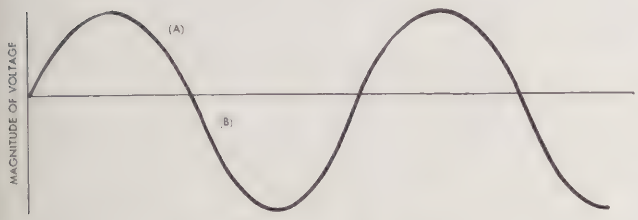


Figure 28. Wave form, self-rectified circuit.
(A) Useful voltage,
(B) inverse voltage.

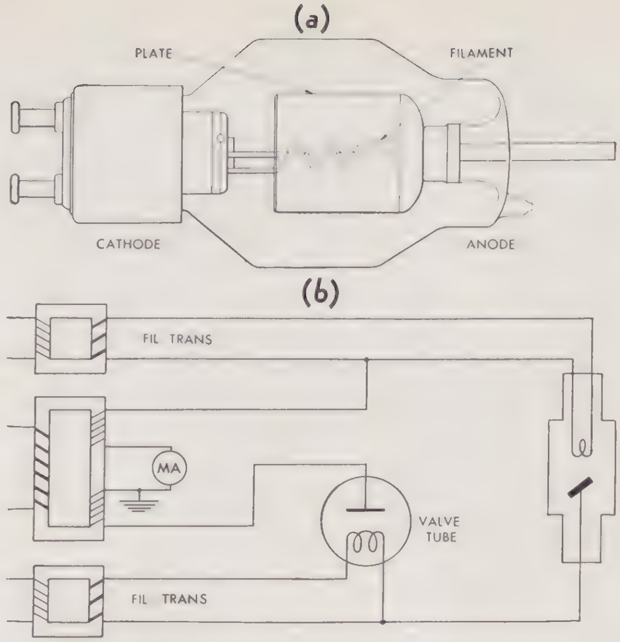


Figure 29(a). Valve tube.
(b). Valve tube in an X-ray circuit.

43. SELF-RECTIFICATION (fig. 26). A roentgen tube permits electric currents to flow through it, and thus emit roentgen rays, but only if the voltage is applied to the tube in such manner that the anode is charged positively with respect to the cathode; that is, the anode must be positive and the cathode must be negative. Opposite direction of voltage prevents the flow of current (electrons) as long as the heat of the target is below that required for electron emission. (See par. 35c.) The voltage of the secondary coil of the high tension transformer is alternating. Normally, when this a-c voltage is connected directly to a hot cathode tube the current will flow only one-half of the time and, at the same time, one-half cycle of the a-c voltage produces roentgen rays; the other half subjects the tube to high inverse voltage. (See fig. 28.) Current flows through the X-ray tube in pulsations, 30 per second, if the power supply frequency is 60 cycles per second. This is called "half-wave rectification." All Army Field X-ray Units are self-rectified.

44. VALVE-TUBE RECTIFICATION. Valve tubes (thermionic rectifiers) are in some respects similar to roentgen ray tubes. (See fig. 29.) They consist of a highly evacuated glass tube with a tungsten filament mounted in one end and a molybdenum plate mounted in the other. The filament is heated by a-c current to approximately 2,000° C., from the secondary of a filament transformer. As high tension voltage is applied to the filament and the plate (the filament being negative with respect to the plate) the current flows through the valve. No current flows if the voltage is applied in the opposite direction. Thus, alternating-currents are rectified by valve tubes. A valve tube, like a roentgen-ray tube, has a saturation current—but valve tubes are normally operated under these saturation currents. Thus, increases of applied voltages result in increase of valve tube current. The voltage drop across a valve tube should not exceed a few hundred volts if filament temperatures are maintained at high values. Manufacturers specify proper heating currents for the valve tube filaments. If these currents are permitted to fall below the specified amperage, potential difference across the tube may exceed saturation values, and thus, result in the emission of roentgen rays. Such emission is undesirable and dangerous. No means of rapid cooling of the valve tube plate is provided; melting temperatures may easily be attained. Since roentgen ray emission is always possible, valve tubes should be located where the patients and technicians are not exposed to them.

45. INVERSE SUPPRESSOR. In the case of certain relatively low milliamperage capacity units (10 to 30 milliamperes), instead of incorporating valve tubes in the high tension circuit for the purpose of rectification, an inverse suppressor may be connected into the primary circuit of the high tension transformer. The purpose of inverse suppressors is to limit partially the amplitude of voltage effective upon the target of the X-ray tube. Inverse suppressors may be constructed on the principle of a

thermionic tube or on the principle of crystal rectification. In either instance, there is provided a shunt resistance in a position parallel to the rectifying component. This shunt resistance provides for the flow of a small quantity of current in the inverse direction to provide for demagnetizing the core of the high tension transformer and thereby maintaining transformer function. This performance is indicated in figure 30. Inverse suppressors are usually used when it is necessary to reduce the bulk and weight of the high tension transformer to a minimum, as for instance when the high tension transformer is contained with the X-ray tube. Small transformers necessarily have relatively poor regulation. In performance, the difference between the voltage for the alternations carrying the load versus the voltage developed by those alternations not carrying the load may be as great as 15 to 20 kvp for load considerations of 25 to 30 milliamperes. The construction features in the tube head (that is, spacing, oil content, etc.) may not tolerate such no-load potentials. It is to compensate for these construction features or to protect shockproof cables that inverse suppressors are utilized.

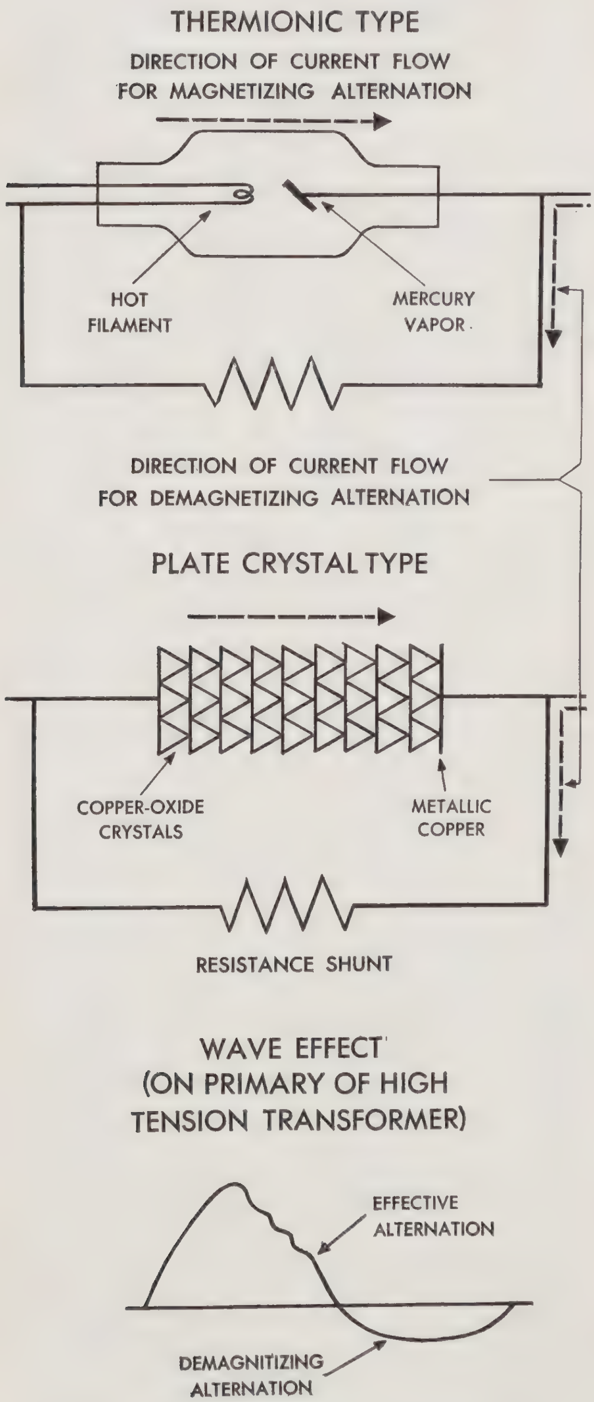


Figure 30. Inverse suppressor function.

46. HALF-WAVE RECTIFICATION. One and two valve tube rectifiers (fig. 31) also provide half-wave rectification. The benefit derived from either one or two valves as compared with self-rectification, is reduction of inverse voltage. A high inverse voltage still exists across the transformer but only a small portion of it is impressed across the X-ray tube (fig. 32), the remainder being divided between the valves. Therefore, more prolonged exposures can be tolerated by the X-ray tube and higher useful voltages can be impressed safely across it without the necessity of excessive insulation around the tube itself.

47. FOUR VALVE TUBE RECTIFICATION (fig. 33). The use of four valves provides for full-wave rectification. Both halves of each cycle of alternating emf are applied in the correct direction for the production of roentgen rays. The tube current is a series of pulsations (that is, at nominal rate of 60 per second in the case of 60-cycle current). The current in the secondary coil of the transformer is still alternating-current. (See fig. 34.)

48. MECHANICAL RECTIFICATION. A four-electrode mechanical rectifier (fig. 35) likewise provides full-wave rectification. The mechanical rectifier is essentially a reversing switch, synchronized by means of a motor with the a-c voltage of the transformer. At each alternation of current, the switch reverses the wire connections between transformer and X-ray tube. Electrical contact between transformer and tube is not continuous, but occur during a short portion of each half cycle, at the instant when transformer voltages are highest. (See fig. 36.) Thus, a more homogeneous band of X-radiation results. This is the only advantage of mechanical rectification over valve-tube rectification. Some disadvantages are: noise, floor space required, unpleasant gases produced, and difficulty of shockproofing. This type of rectification is seldom used, today.

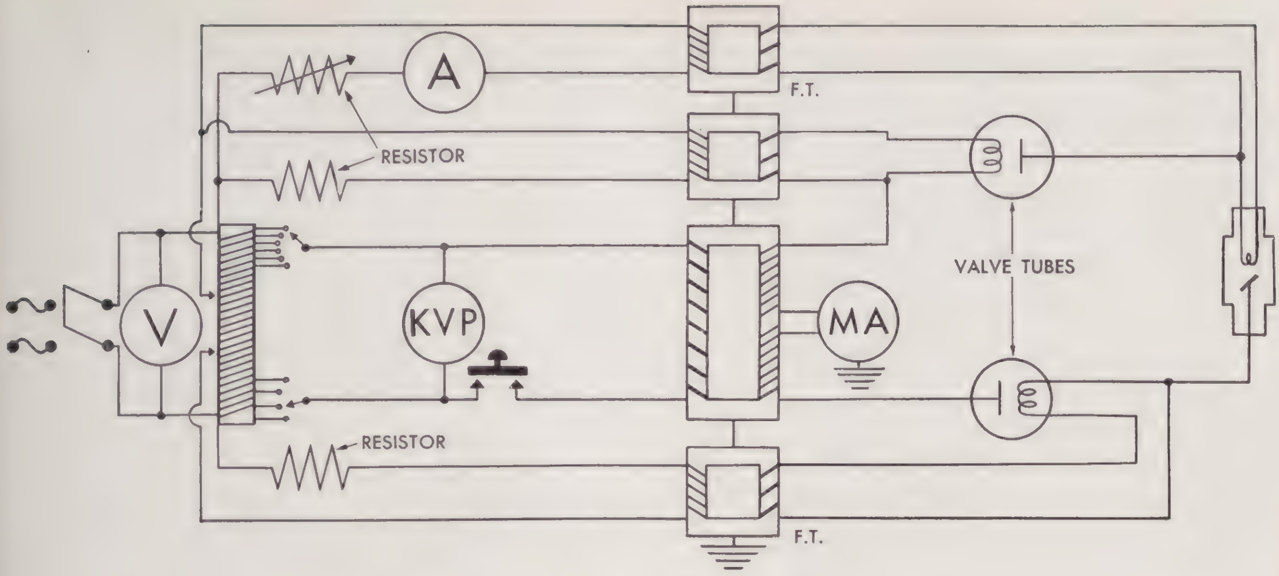


Figure 31. Two valve half-wave rectified circuit.

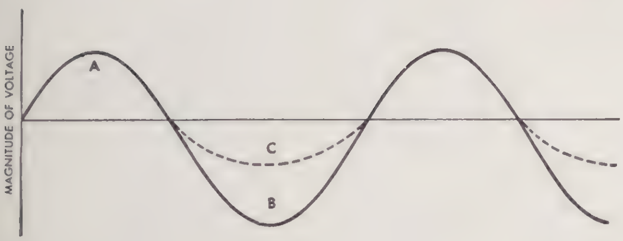


Figure 32. Wave form, half-wave rectified circuit.
———— Transformer
– – – Tube voltage
(A) Useful voltage,
(B) Transformer inverse voltage,
(C) Tube inverse voltage.

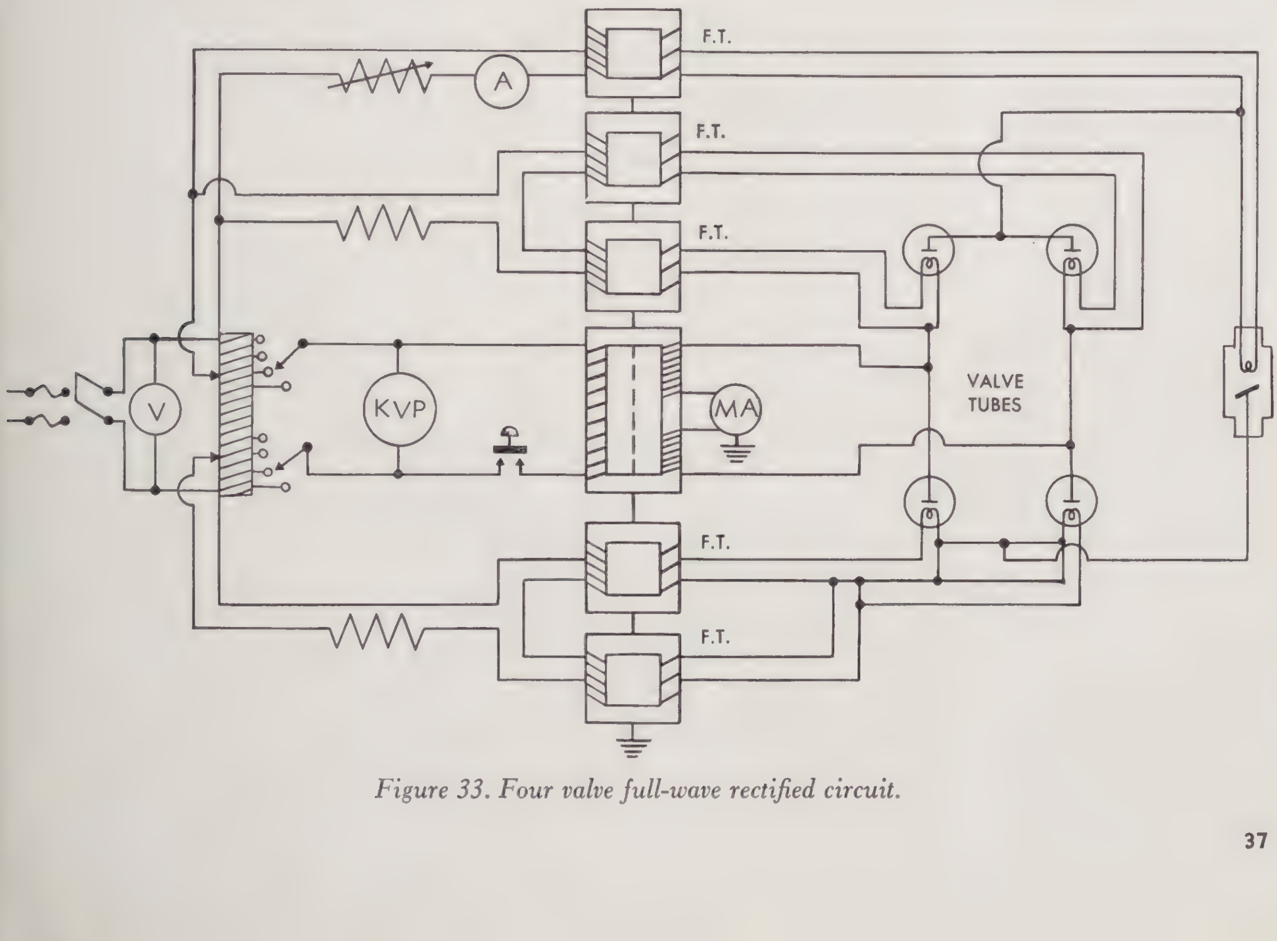


Figure 33. Four valve full-wave rectified circuit.

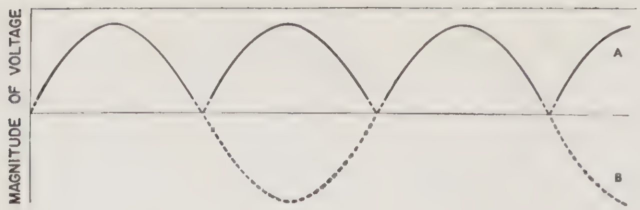


Figure 34. Wave form, full-wave four-valve rectified circuit.
(A) Wave form of transformer and Roentgen tube voltages.
(B) Wave form of transformer.

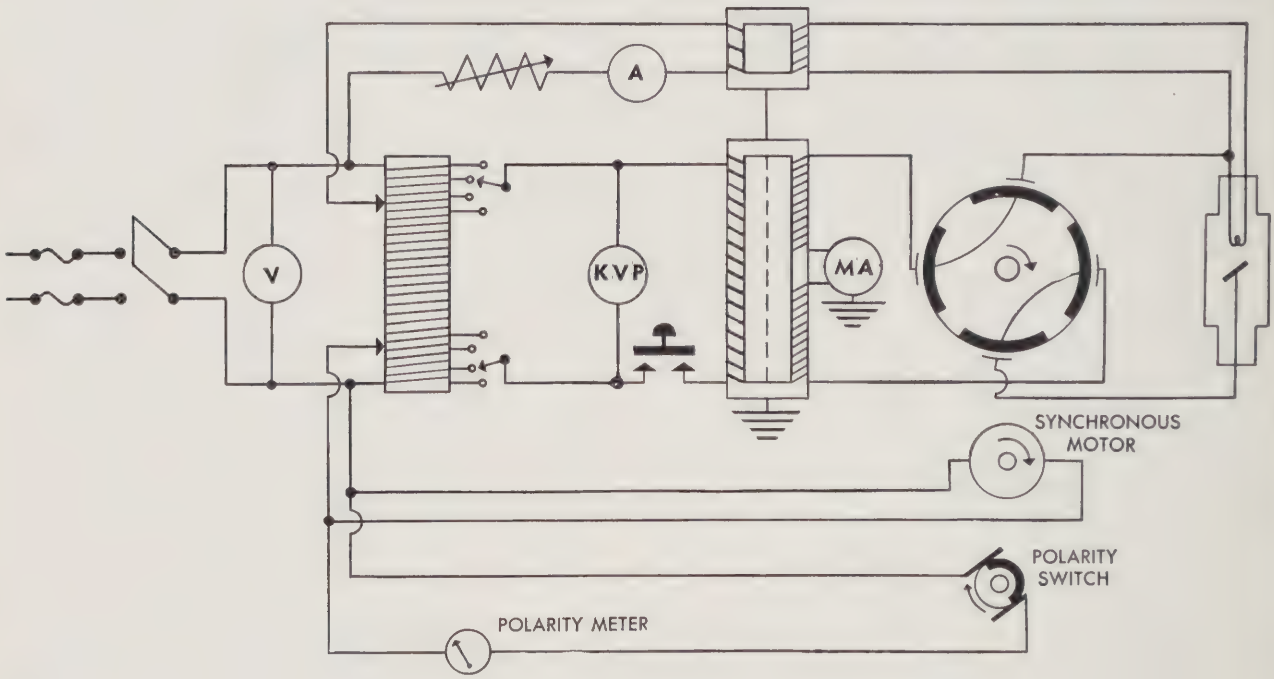


Figure 35. Mechanical full-wave rectified circuit.

49. SHOCKPROOF AND NONSHOCKPROOF EQUIPMENT. The term "shockproof" equipment implies the fact that all external parts of the machine, both low and high voltage components may be approached to very short distances, or even touched, without danger of electrical shock. The X-ray tube, rectifiers, transformers, and wires connecting them are completely surrounded by insulators. These shields are connected to ground. Since, normally, the human body is also at ground potential, contact of the body and these grounded metallic shields does not result in current flow. Some portions of nonshockproof machines, tube, rectifiers, transformer terminals, milliammeter (fig. 37), and filament ammeter are not covered by grounded shields, and thus, to approach them within 2 feet may result in a high voltage discharge to the body. *Distance* is the best protection when working with such arrangements.

50. POWER AND LINE REQUIREMENTS. a. Standard requirements. Most American made roentgen-ray machines are designed to operate on either 110 volts or 220 volts, 60-cycle, alternating-current. The power requirements increase with the tube current and tube voltage applications of the machine. Likewise, line requirements, such as size of wire, fuses, and switches, increase with machine capacity. (See table VII, app. V.)

b. Foreign electrical systems. Electrical systems of Europe, Africa, and Asia are not standardized to the same degree as found in the United States. The roentgenologist and his roentgen ray technicians must exercise considerable ingenuity and skill to solve some of the electrical problems of Foreign Service. Many European systems are d-c (direct-current). Before d-c power can be used in a roentgen-ray machine, it must be converted to a-c (alternating-current). A rotary converter is used for such a

purpose. Approximately 25 percent of the power is lost in the conversion. Thus, an autotransformer, tapped normally for 110 volts a-c, designed for 60-cycle current operation, will have to be tapped for 80 volts a-c when used with a converter. Frequencies lower than 60 cycles per second may be encountered. The electrical type of timers designed for 60-cycle current will not measure correct exposure intervals when connected into circuits of lower frequencies of current. The error may be too great to neglect, and correction for each roentgenographic exposure in accordance with the variation in cycles, will be necessary. Transformers designed for 60-cycle

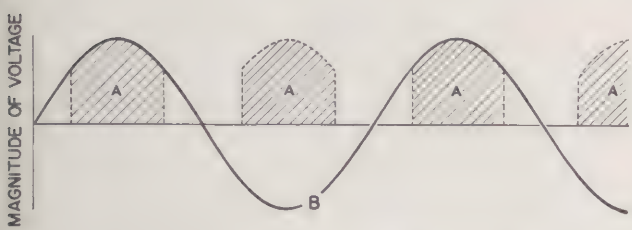


Figure 36. Wave form, full-wave mechanical rectified circuit.
(A) Roentgen ray tube voltage.
(B) Transformer voltage.

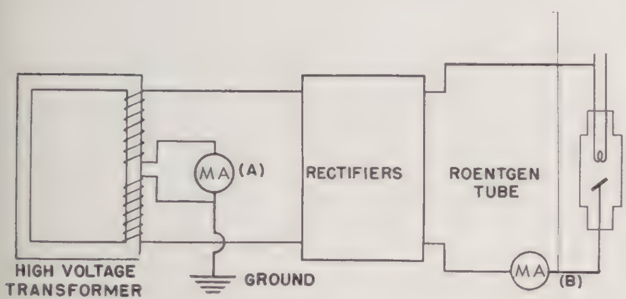


Figure 37. Positions of the milliammeter.
(A) Shockproof units.
(B) Nonshockproof units.

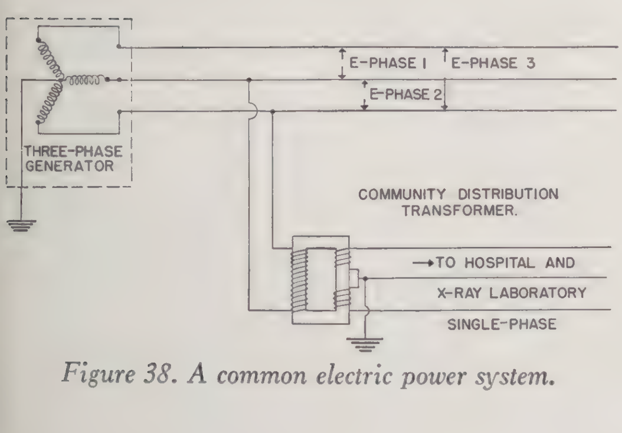


Figure 38. A common electric power system.

current will usually operate safely and satisfactorily on 50-cycle current. However, most transformers will become over-heated and likely "burn out" if connected into 25-cycle current. The manufacturer marks on the transformer, its rated frequency capacity.

c. **Phase.** Practically all X-ray equipment is designed to operate on single-phase current. Yet, it is common practice, both in the United States and in other parts of the world to lead three-phase current at least to the distribution box of a building. Connections can be made into such leads so as to provide for single-phase current selection. (See par. 24.) A three-phase power supply may be provided by three wires or by four wires. (See fig. 38.) In case of the latter, it must be realized that one of the four wires is a neutral lead. Three-phase currents are most frequently supplied at 200 to 240 volts. The voltage across any pair of the three-wire system (or any pair of the "hot" three wires of the four-wire system) would be of the voltage mentioned—200–240 volts. Connections of this sort would provide for such voltages and *single-phase* power supply. Single-phase power supply, with a voltage in the range of 100–120 can be obtained from such 200–240 three-phase systems by making connections to any one of the three-phase ("hot") leads and to the neutral lead—or in the case of a three-lead system, the circuit may be completed through a ground produced by making connections to a plumbing system or to earth (that is, having the X-ray circuits interposed between the "hot" lead and the ground connection). Therefore, low milliamperage equipment may be connected in this manner. In the case of high milliamperage equipment, the autotransformer may be connected across any two of the "hot" leads of the three-phase system. If there be any doubt as to the voltage pertaining to such leads, it is important that connections of X-ray equipment be not blindly made; one should not risk break-down of equipment which is so expensive and in forward areas, so difficult to obtain. Preliminary testings of the leads should be accomplished. This can be done by first producing a ground, if possible; connecting one lead of a test lamp to it and then placing the other lead to each of the terminals. In case of a four-wire system, it will be noted that the test lamp will not light when connected to ground and one of the four leads. Such evidence, of course, identifies the neutral lead. Test connections with each one of the other three leads (or any of the three leads of a three-wire system) should produce a normal lighting of the lamp. Further checking may be accomplished by having two 110 volt lamps in series and adapting contact for circuit connections with any two of the "hot" wires. Again, with two lamps in series, a normal brilliance of lighting should be obtained. Such testing should identify the proper connection for one or another circuit and one or another capacity unit.

SECTION IV. CAPACITY OF ROENTGEN-RAY MACHINES

51. GENERAL. Roentgen machines are classified according to function. Two general types are: diagnostic and therapeutic. The physical principles underlying all of them are alike and, therefore, may be discussed together. Diagnostic and therapeutic machines may differ in capacities for X-ray production. Diagnostic machines are of two general groups: heavy duty (90 kvp or higher potentials with loads of 100 ma or greater) and light duty (limits of 85 kvp or less, with loads of 30 ma or less). The former are large, bulky, nonmobile units; they are installed in fixed positions and therefore allotted only to general hospitals. Light duty machines are small, portable or mobile units, capable of being transferred readily from room to room or either from one building to another. The U. S. Army field units are examples of light duty machines.

52. FIELD X-RAY UNIT, ITEM NO. 96085. This unit must be operated on 100–130 volts, 50–60 cycle, a-c. The newer designs of this unit have an automatic relay and may be operated on either 100–130 or 200–240 volts. In the event that community service is not available the unit should be operated from the Gasoline Electric Generator, Item No. 96060. The X-ray unit has the following capacity, depending upon the type of power supply:

Gasoline Electric Service	*Community Service*
Roentgenoscopy—5 ma, 85 kvp, continuously	5 ma, 85 kvp, continuously
Roentgenography—15 ma, 85 kvp up to 50 secs	30 ma, 85 kvp up to 15 secs
Therapy—4 ma, 100 kvp continuously	4 ma, 100 kvp continuously

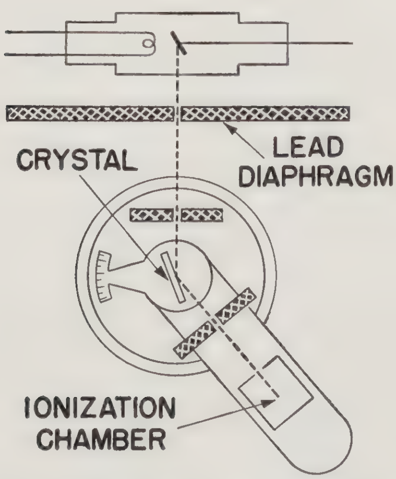


Figure 39. Roentgen ray spectrograph for measuring wavelengths.

53. FIELD X-RAY UNIT, ITEM NO. 96215. This unit may be operated on 100–130 or 200–240 volts, 50–60 cycle, a-c. The same power supply conditions apply to this item as for Item No. 96085. Exposures can safely be made as follows:

Roentgenography	—15 ma, at 80 kvp 10 secs exposure 40 secs rest, indefinitely
Roentgenoscopy (Foreign body localization)	—5 ma, at 80 kvp 10 secs exposure 2 secs rest, indefinitely

SECTION V. ROENTGEN-RAY SPECTRA: MEASUREMENT OF ROENTGEN RAYS

54. EMISSION SPECTRA. a. Characteristic spectra. The roentgen rays emitted from a tube are heterogeneous in wavelengths; that is, many different wavelengths are contained in the beam. Examination of the spectra—the sum total of all wavelengths—is done by means of roentgen-ray spectrograph (fig. 39), it reveals the interesting fact that the intensity of ray distribution among different wavelengths is somewhat regular from the minimum to the maximum wavelength, except at well defined points, where intensity of radiation rises and falls abruptly. (See fig. 40.) The exact wavelengths at these critical points are found to be "characteristic"—that is, related to the substance of the target. Wavelengths in the characteristic spectra fall into groups or series; the latter are described, beginning with the shortest and continuing to the longest wavelengths, the *K*, *L*, *M*, *N*, etc., series. Each element has characteristic series of rays but the wavelength values in one series are different for each element. For instance, the *K* series of tungsten includes a small group of wavelengths in close range of .208 Å, while that for copper is of wavelength range 1.537 Å.

b. Continuous spectra. In addition to characteristic radiations, there are emitted from the target radiations of all wavelengths down to a certain minimum. The sum total of these rays is called the continuous roentgen ray emission spectra. The minimum wavelength (fig. 40) in the continuous spectra is given by:

$$\underset{\lambda}{\overset{\lambda}{\text{(Minimum)}}} = \frac{12.354}{\text{kvp}}, \text{Å}$$

where λ (lambda) is minimum wavelength and kvp is the maximum value of kilovoltage applied to the roentgen ray tube. The maximum wavelength of the continuous spectra is that one which barely penetrates the wall of the tube. The wavelength at which maximum intensity occurs is approximately 1.5 times the minimum wavelength.

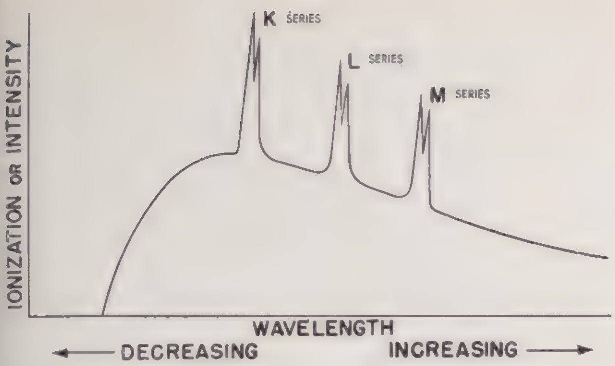


Figure 40. Roentgen ray emission spectrum.

55. ABSORPTION SPECTRA. a. True absorption. When roentgen rays are directed upon a portion of the body, different events occur. Some rays are absorbed, some are scattered, and some pass entirely through without being changed. The latter are called transmitted "primary rays." (See fig. 1.) In the event of true absorption, entire quanta of roentgen rays are transformed, on collision with atoms, to different types of energy; that is, heat (very small) and *photoelectrons*. (See fig. 41.) The photoelectrons, in turn, dissipate their energy by ionization. True absorption is independent of the physical state of the absorber. Thus, one gram of ice, one gram of water, and one gram of steam will absorb equal portions of roentgen rays. Elements of higher atomic weights in the roentgen ray path have greater true absorption.

b. Scattering absorption. Scattering of roentgen rays occurs when a quantum of ray energy (fig. 41) hits an electron, divides its energy with the electron and then continues in a different direction as a new ray of a longer wavelength. On the other hand, the quantum may merely change direction upon collision without a loss of energy. The former type of scattering is called "modified (Compton effect) scattering"; the latter is called "unmodified." The electrons associated with modified scattering are called "recoil electrons." They, too, dissipate their energy by ionization. Scattering increases with volume of tissue in the roentgen ray beam. Both photoelectrons and recoil electrons give rise to new radiations called "secondary" rays.

56. MEASURE OF ROENTGEN RAYS. a. Quantitative. (1) *General.* A heterogeneous beam of roentgen rays is characterized by its intensity and penetrating power. Intensity is a quantitative characteristic; penetrating power of wavelength is a qualitative characteristic. The quantitative measure of roentgen rays is, thus, a measure of intensity. (See table VIII, app. V.) Intensity of radiation is the quantity of radiant energy passing perpendicularly through each square centimeter of surface. The physical factors which determine intensity are: tube kilovoltage, tube milliamperage, filter, and distance. There is no true, simple mathematical relationship between intensity and these four factors. Certain factors are related, however, by the following ratios:

$$\frac{I_1}{I_2} = \frac{Ma_1}{Ma_2} \quad \frac{I_1}{I_2} = \frac{D_2^2}{D_1^2} \quad \frac{I_1}{I_2} = \frac{kv_1^2}{kv_2^2},$$

for kv greater than 70 kilovolts, where I_1 and I_2 are intensities of radiations for milliamperages, Ma_1 and Ma_2, for distances, D_1 and D_2, and for kilovoltages, kv_1 and kv_2 respectively.

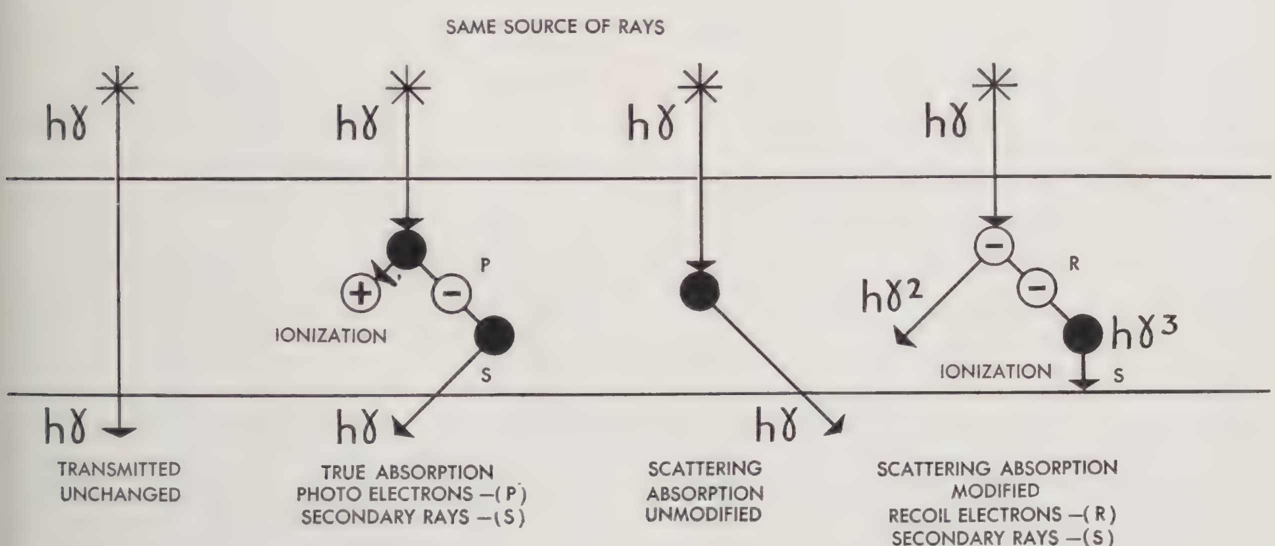


Figure 41. Types of roentgen ray absorptions.

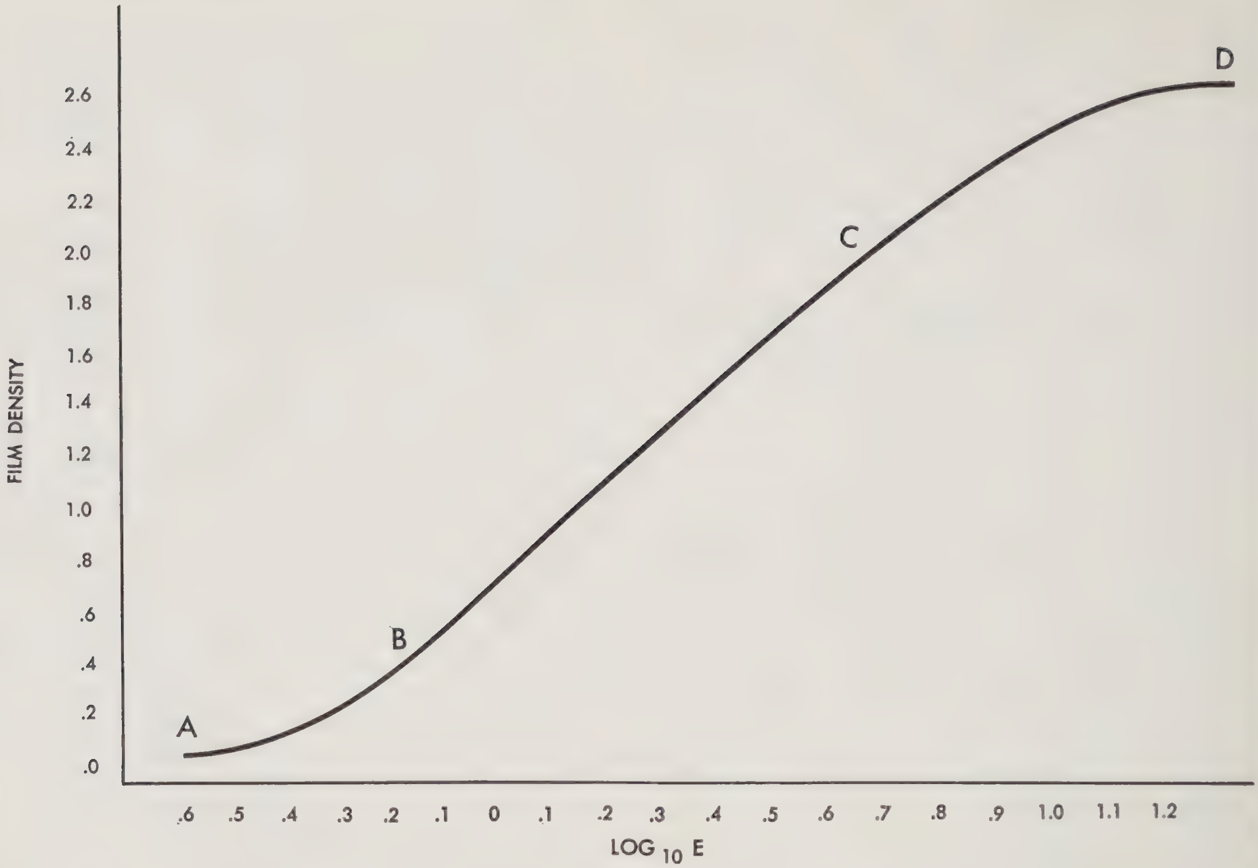


Figure 42. Photographic density curve of roentgen-ray films.

(2) *Photographic.* There are several physical methods of measuring roentgen ray intensity but only two are used commonly. They are photographic method and ionization method. The photographic method is less accurate than the ionization method. Roentgen rays activate the silver compound in the roentgen-ray film in such a way that when the film is "developed," black silver is deposited in the emulsion of the film. Quantity of silver, or density of film is related to the radiation exposure. (See fig. 42.) Film exposure E is equal to $I \times t$ when I is the intensity of radiation and t is the time of exposure. Density of film can be measured by means of a densitometer. The relationship between density and exposure is shown in figure 42. There is a region of density (*BC*)—the method is more accurate in this region—wherein radiation exposure and density are directly proportional. On either side of this region (*AB* or *CD*) the relationship is not linear. The method is too inaccurate to be used in these regions. This method of measurement is widely used in connection with roentgenography. Absolute values of intensity are not determined by the photographic method; only relative values are measured, such as comparison of radiation output of two machines or relative outputs of the same machine when operated at different factors.

(3) *Ionization.* (*a*) *General.* Roentgen rays possess the power to make gases, and become fairly good conductors of electricity at atmospheric pressures. Ions, positive and negative, are liberated (ionization) and are measured as electric current. The current is a measure of the radiation intensity. Ionization currents are measured by means of air chambers. The unit of roentgen ray quantity is called the "roentgen" or "r-unit" and is designated by the small letter "r." One roentgen is defined as the quantity of roentgen rays which, when secondary electrons are fully utilized and secondary radiations from the wall of the ionization chamber are avoided, produces in .001293 grams of atmospheric air, a saturation current of one electrostatic unit. This current in amperes is about 3×10^{-10}. This exceedingly small current can be measured only by sensitive instruments. The mass of air referred to is the weight of one cubic centimeter of air at 0° C., and 760 mm Hg pressure.

(*b*) *Standard ionization chamber.* Several chambers, called standard ionization chambers, have been constructed to measure the r-unit exactly as it is defined. (See fig. 43.) There is one standard chamber in the laboratory of the United States Bureau of Standards. Other standard chambers are scattered about the country in various institutions.

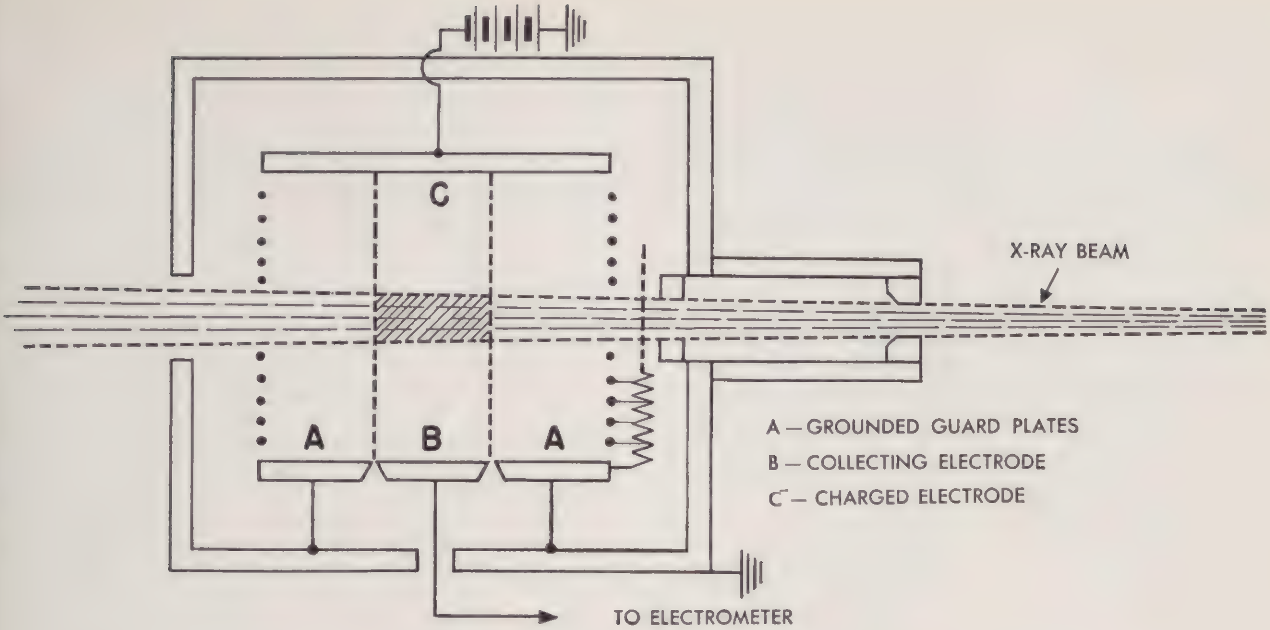


Figure 43. A standard ionization chamber.

(*c*) *Secondary chambers.* The standard chamber, although portable, is not designed for routine tests of roentgen ray intensities. Secondary chambers, called r-meters, are made for this purpose. (See fig. 44.) They are small, rugged in construction, and easily carried. They are composed with the standard chamber in order to insure accuracy of their response. Their scales are calibrated in roentgens. By means of these r-meters, radiation intensity is measured and expressed in roentgens per unit of time.

b. Qualitative. (1) *General.* The complete evaluation of the quality (penetrating power) of a roentgen-ray beam involves the measure of all wavelengths in the beam. The latter can be done by means of a roentgen ray spectrometer. (See fig. 39.) This method, however, is laborious and necessitates costly and delicate apparatus and, therefore, is not practical in the medical roentgen-ray laboratory. An expression of kilovoltage and filter is not satisfactory because it tells only a part of the story.

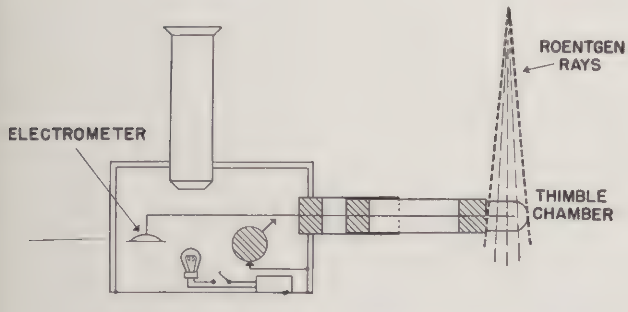


Figure 44. A secondary roentgen meter.

(2) *Aluminum ladder.* Comparative measurements of quality can be accomplished by means of an aluminum ladder. The ladder consists of pieces of aluminum of different lengths, but of equal thickness, piled on top of each other. When one end of all pieces are together, the pile of aluminum will present a ladder or stairsteps effect of several different thicknesses. The portion of a roentgen-ray film covered by the ladder and exposed to roentgen rays will show, on development, a series of density values. The minimum film density will lie under the thickest aluminum, while the maximum film density will lie under the thinnest aluminum. The aluminum equivalents of different radiation beams can thus be found and the quality of radiation, thereby, roughly compared.

(3) *Absorption curves and half-value layers.* A more complete evaluation of radiation quality is obtained from absorption curves and half-value layers. (See fig. 45.) Absorption curves are graphical relationships between thickness of absorbing material and intensities of effective radiation. The intensities are measured with the use of an r-meter. Its ionization chamber is positioned at a constant level (usually a practical focal-film or focal-skin distance) and measurements are made under conditions of no

filter being inserted into the primary beam; then, with 1-mm, 2-mm, 3-mm, etc., thicknesses of aluminum, copper, or other filter substance inserted. From the plotting of such relations there can be interpolated the thickness value of filters responsible for absorbing 50 percent of the radiation initially considered. The half-value layer, an expression of quality of X-radiation, is defined in terms of such absorbing filter thicknesses. For roentgen rays as produced with kilovoltages of 20 to 120 kv (peak), half-value layers are usually expressed as millimeter thicknesses of aluminum; for those produced by kilovoltages of 120 to 400 kv (peak), the expressions are in terms of millimeter thicknesses of copper, while for higher kilovoltages, the half-value layer may be expressed in terms of tin.

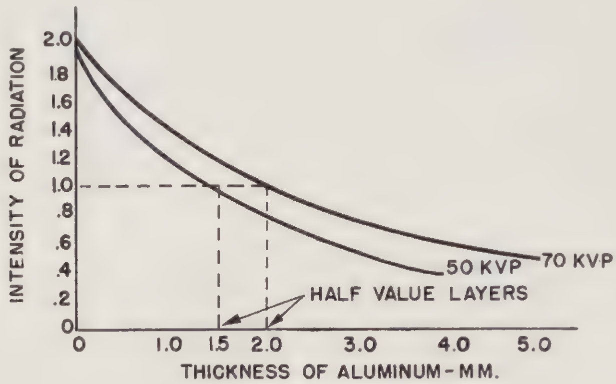


Figure 45. Aluminum absorption curves—Army field unit.

CHAPTER 3

FIELD X-RAY EQUIPMENT

57. GENERAL. For the theater of operations, the designing of X-ray equipment has been governed by at least three axiomatic principles:

a. Versatility of adaptation to the extent that each piece of equipment may function not merely for a single purpose but for several requirements and installations.

b. Portability to the extent that disassemblage of each item can be easily accomplished and that the component parts can be carried.

c. Practicability of design to the extent that the equipment can serve the requirements of function in peacetime installations as well as in the zones of combat.

58. SUPPLY CATALOG LISTINGS. In accordance with these principles, the following items have been developed:

Item No. 96025, X-ray Field Unit, Chest, Film, X-ray.

Item No. 96055, X-ray Field Unit, Dryer, and Loading Bin Combination: Complete with air circulator, for field processing unit.

Item No. 96060, X-ray Field Unit, Generator, Gasoline, Electrical: Complete in chest.

Item No. 96070, X-ray Field Unit, Grid, Portable: Replacement grid for 96145; also suitable for use in bedside or similar types of radiography.

Item No. 96085, X-ray Field Unit, Machine, X-ray, Mobile, Complete: For field fluoroscopy, roentgenography and superficial roentgenotherapy. (Consisting of 96086, 96087 and 96088.) (1 pair of gloves, 1 apron and 1 pair of goggles included with each assembly.)

Item No. 96086, X-ray Field Unit, Transformer Chest, MD X-2.

Item No. 96087, X-ray Field Unit, Tube Unit, Chest, MD X-3: (For tube replacement see 96209).

Item No. 96088, X-ray Field Unit, Control Unit, Chest, MD X-4.

Item No. 96090, Chest, MD, X-1: Chassis for converting 96085 to a mobile X-ray unit for bedside use.

Item No. 96115, X-ray Field Unit, Processing Unit, for Darkroom: For film processing.

Item No. 96117, X-ray Field Unit, Processing Unit, Auxiliary Wash Tank.

Item No. 96145, X-ray Field Unit, Table Unit: For field fluoroscopy, foreign body localization and roentgenography. Complete in chest.

Item No. 96175, X-ray Field Unit, Tent, Darkroom: For fluoroscopy and/or film processing.

Item No. 96191, X-ray Field Unit, Biplane Marker and Reorientating Device. (See ch. 13.)

Item No. 96205, X-ray Field Unit, Shockproof Cables.

Item No. 96208, X-ray Field Unit, Tube Adapter: For utilizing X-ray tube of 96085 with 61580.

Item No. 96209, X-ray Field Unit, Tube, X-ray: With mounting hanger.

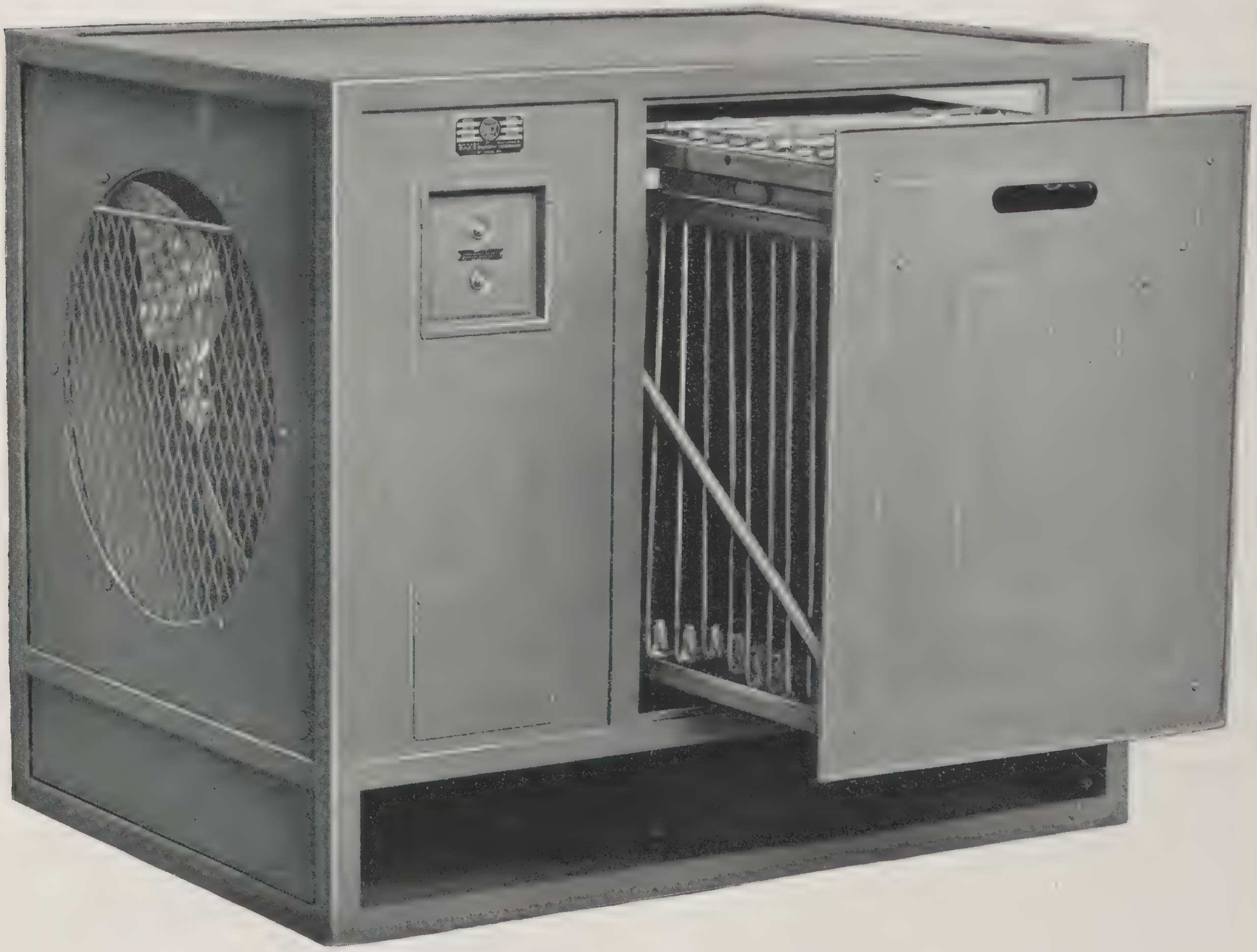
Item No. 96215, X-ray Field Unit, Fluoroscopic, Foreign Body Localization, Complete: With table unit; shockproof, 15 MA machine for use with both 110V and 220V. (1 pair of gloves, 1 apron and 1 pair of goggles included with each assembly.)

Item No. 96245, X-ray Field Unit, Kit, Spare Parts and Repair, X-ray Machine.

Item No. 96246, X-ray Field Unit, Kit, Spare Parts and Repair, Table Unit.

59. FILM CHEST, ITEM NO. 96025. This is simply a standard Medical Department field chest containing an inner lining of sheet lead. The sheet lead is of such thickness (approximately 1.5 mm) that, with the opacity of the chest itself, there is provided protection against X-rays having a quality such as produced with kilovoltages as great as 100. Since it is anticipated that most of the film processing will be done within the tent (Item No. 96175), which is nonprotective against X-radiation, it is important that all reserve films be kept in the chest. The usual wall protection afforded by a properly constructed darkroom likely would not be available. This special chest is for use particularly at the evacuation hospital and for those occasional times when films would be wanted for use in a truck at the mobile surgical hospital. It is not recommended for the shipment of cassettes, cardboard holders, or film

(*1*) *Film and cassette loading bin.*



(*2*) *Dryer.*
Figure 46.

preservers. These should be packed in the ordinary Medical Department chests. The additional weight of the lead lining contained in the special chest is unnecessary and would be undesirable.

60. DRYER AND LOADING BIN, ITEM NO. 96055. This unit is intended for general hospitals, station hospitals, and evacuation hospitals. Occasionally it may be needed for use in a truck. It is portable, being composed of two compartments. The upper compartment is completely lead-lined to afford protection against X-radiation. It consists of two sections: a film storage section occupying the right half, and a loaded cassette section occupying the left half. Racks have been provided in each of these two sections to accommodate the three standard dimensions of X-ray films as used by the United States Army: 8- by 10-inch, 10- by 12-inch, and 14- by 17-inch films. The lower compartment of the unit contains a drawer type of drying rack, a heater, fan, and a floor loading shelf. The drying rack has accommodations for 18 films as suspended on standard film hangers. After mounting the upper compartment (the film and cassette loading bins) onto the lower compartment (the dryer), there is provided a loading bench. The fixation of these two

Figure 47. Loading and drying bin assembled.

compartments is accomplished by means of a spring type of lock which will be found on the inside of the base compartment and beneath its top. This lock must be disengaged before attempting to disassemble this unit in case of having to move it to a new installation. These construction features are indicated in figures 46 and 47.

61. GASOLINE GENERATOR, ITEM NO. 96060. This generator is a specially designed gasoline electrical generator. (See fig. 48.) It is intended particularly for use where community electrical supply is not available and for emergency needs at other hospital installations. Its functioning capacity is such as to permit the delivery of 2,500 watts at unity power factor. *No small, portable electrical generator other than that with the identification "Item 96060" should be used to operate the X-ray machine.* When the electrical supply is provided by the Corps of Engineers, precaution should be taken that the generator is of capacity no less than 5,000 watts and productive of 60-cycle, 100–130 volts, a-c, single-phase. When the capacity load of a generator is taxed, there ordinarily results a slowing down in the speed of its action. With a sudden release of the load, as intermittently occurs during roentgenoscopy,

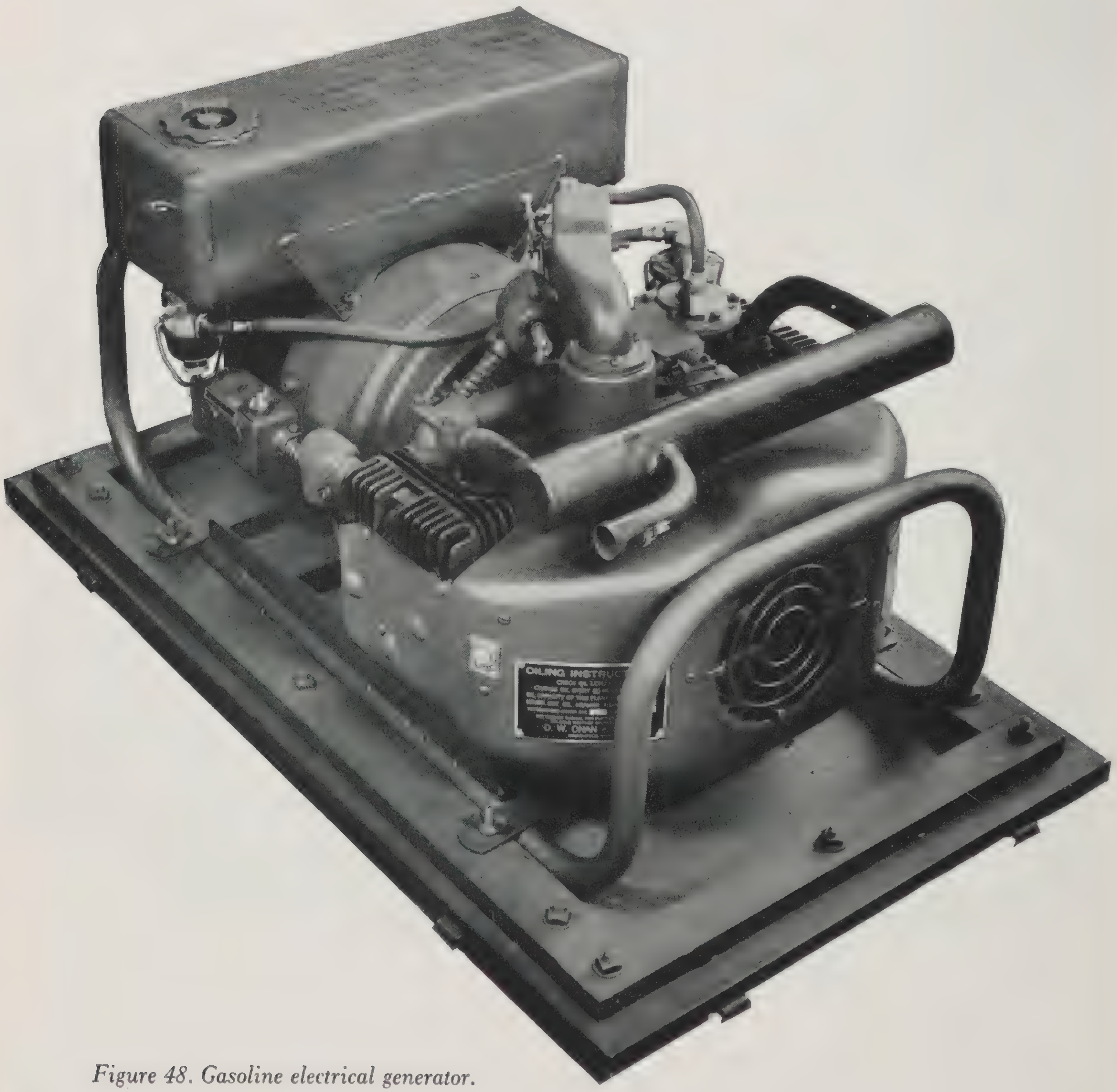


Figure 48. Gasoline electrical generator.

Figure 49. Item 96085 in field chests.

the engine is likely to "race" unless its governor control is adequate. Since X-ray machines function by way of two main avenues of circuits (the autotransformer and the main transformer circuits as one load, and the filament transformer circuit as a parallel load), when the load of one is released, the load of the other is likely to be increased. Extensive testings have proved that with certain types of portable gasoline electrical generators the governor action is so inadequate in this respect that with release of the main X-ray load there results an overload upon the filament of the X-ray tube, and the filament is soon destroyed. The caption "Item 96060" applies to generators which have been tested and which have been found satisfactory in this respect. The requirement of immediate response to the governor is only one of the prerequisites. It is a most important one, however. Other performance characteristics considered are: surge voltage, inverse voltage, and distortion of wave form. These characteristics are especially important because of utilizing self-rectification and because of having the X-ray tube detached from the high tension transformer with connections by way of shockproof cables. When operating with the X-ray machine unit, the surge of inverse voltage must not exceed the useful voltage by more than 15 kvp with the useful kvp of 85 and a milliamperage of 25. The kilovoltage calibrations of the prereading voltmeter have been made on the basis of the wave form of the average community line. With great variation in wave-form performance for the same autotransformer settings, the resultant peak kilovoltages may be high or low in relation to the calibrated values, depending upon whether the wave form of the current supplied more closely simulates a true sine wave or whether it is further distorted from it as compared with that of a community line.

62. GRID, PORTABLE, ITEM NO. 96070. This item is a wafer type of grid included with the later models of Item No. 96145 and Item No. 96215 or it may be requisitioned separately for general use. The lead strips of this grid are unusually thin. There are 55 strips per inch width of the grid itself—thus, even though it is a stationary type, grid marks are inconspicuous. The lead strips are focused. In the case of the first several hundred of the wafer grids which were purchased by the U. S. Army the spacing of the lead strips was such as to provide a true centering (grid radius) at 36 inches; later constructions have provided for true centering at 30 inches. The older type can be identified by their dimensions —17- by 17-inch versus the dimensions of the later type, which are approximately 14- by 17-inch. This feature in the grid was changed in order to provide adaptability of it to roentgenoscopy as well as for roentgenography. The grid ratio of both of these types is 5 to 1. Because of the fact that the lead strips are focused, it is important that the top side of the grid be placed toward the patient and X-ray tube (that is, the opposite side toward the film or fluoroscopic screen). For a 10-centimeter thickness of part it is necessary merely to increase the milliampere-second factor to twice that required if the grid were not used (whereas with moving grids—"Potter Bucky" diaphragms—approximately three times the milliampere-seconds is required for this grid ratio).

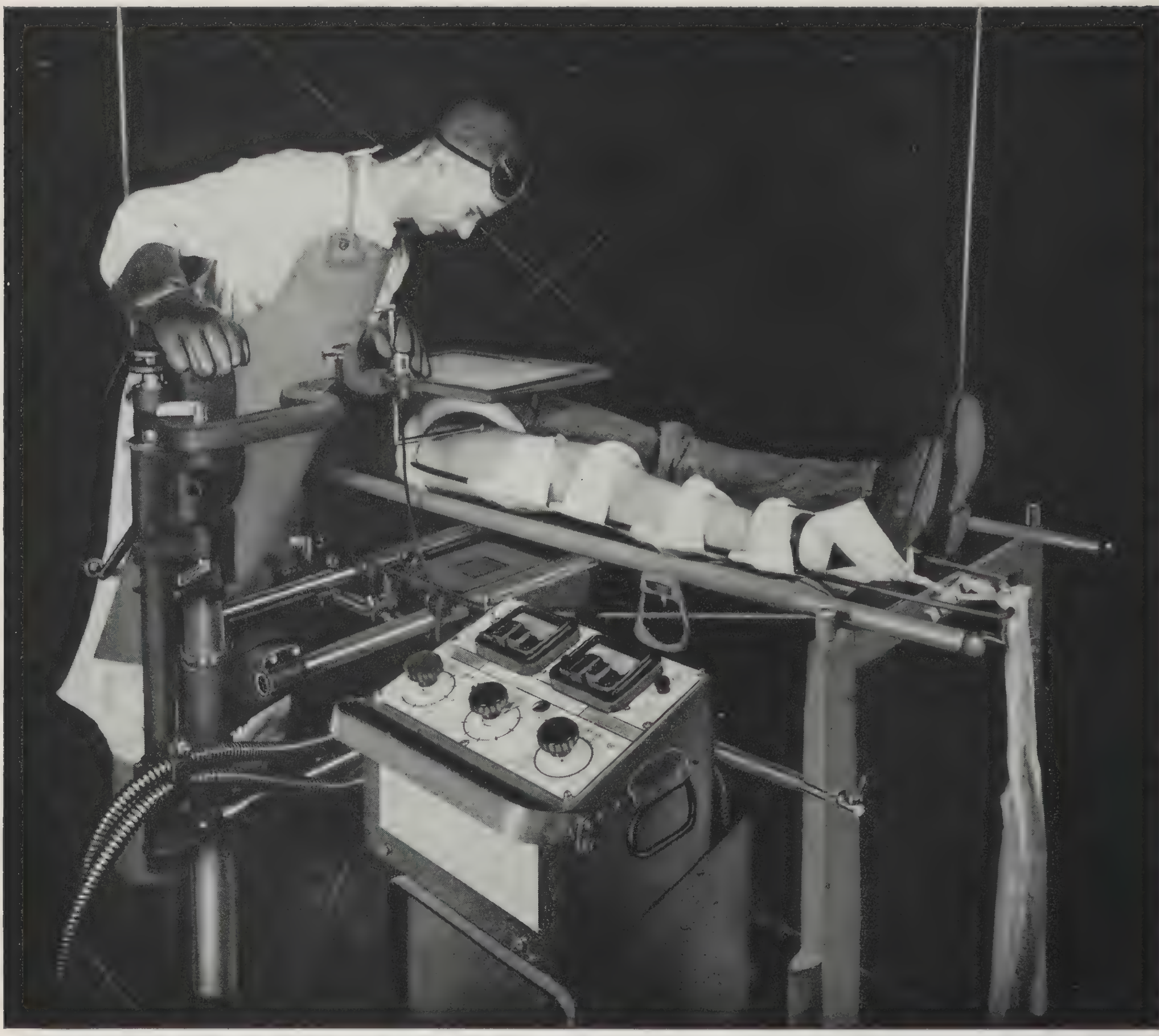


Figure 50. Foreign body localization. Item 96085 adapted to Item 96145 within tent (Item 96175).

63. X-RAY MACHINE UNIT, ITEM NO. 96085.
a. General. This item is intended for all types of hospital installations. It is packed in three field chests. (See fig. 49.) Two of these chests are modified Medical Department field chests; the other one is of special construction for accommodation of the high tension and filament transformers. The X-ray tube in its housing is packed by setting it in a nest supported by eight springs which are attached to the inside corners of a compartment contained in one of the Medical Department field chests. In addition, this particular chest accommodates a drum for packing the two shockproof cables, as well as smaller items such as the filters (to be used in roentgenotherapy) and the several aperture diaphragms. This chest has a gable type of superstructure which has been added in order to emphasize that the chest should be placed on end during transit. This is important in order to provide the greatest protection to the X-ray tube. The second standard Medical Department field chest is modified for accommodations of the control unit, the interconnecting cables, the timer, and the foot switch. A lead apron, a pair of lead-impregnated gloves, and a pair of goggles can be accommodated in this chest. This unit has been designed to operate on line voltages between 100 and 130, with 50–60 cycle, single-phase, alternating current. (See par. 52.) In terms of milliamperage, its maximum capacity is 30. The construction of the high tension transformer is such as to tolerate 60 milliamperes but the design of the autotransformer prohibits this. The reserve capacity has

been provided in order to obtain the desirable minimal inverse voltage. Regardless of the fact that this unit is self-rectified, the inverse voltage exceeds the useful voltage by less than 10 kvp—a most important feature.

b. Applications. In conjunction with the X-ray table unit (Item No. 96145) or the mobile X-ray chassis (Item No. 96090), this X-ray machine unit is adaptable nine ways (figs. 50 through 55): horizontal roentgenoscopy, foreign body localization by means of a rapid roentgenoscopic method (ch. 12), sitting roentgenoscopy, standing roentgenoscopy, to the extent of accommodating routing chest studies and also gastrointestinal studies, horizontal roentgenography using focal film distances up to 45 inches with the patient on the litter at table height, 6-foot vertical chest studies, 6-foot horizontal chest studies, the patient lying on the litter upon the floor, ordinary bedside work in the wards, by means of mounting the component parts of the X-ray machine upon a mobile chassis, and superficial roentgenotherapy, to the extent of milliamperage capacities of 4 and kilovoltage potentials up to 100.

c. Precautions and general instructions are inscribed on the top of the control. (See par. 79.) Information is contained in the instruction manual as to packing and assembling the unit. This manual will be found in the tool compartment contained in the base portion of the control. Similar information is also provided by an instruction placard which is located on the inside of the lid of the two modified Medical Department field chests.

d. Item No. 96086 is the transformer chest MD X-2; Item No. 96087 is a tube unit chest MD

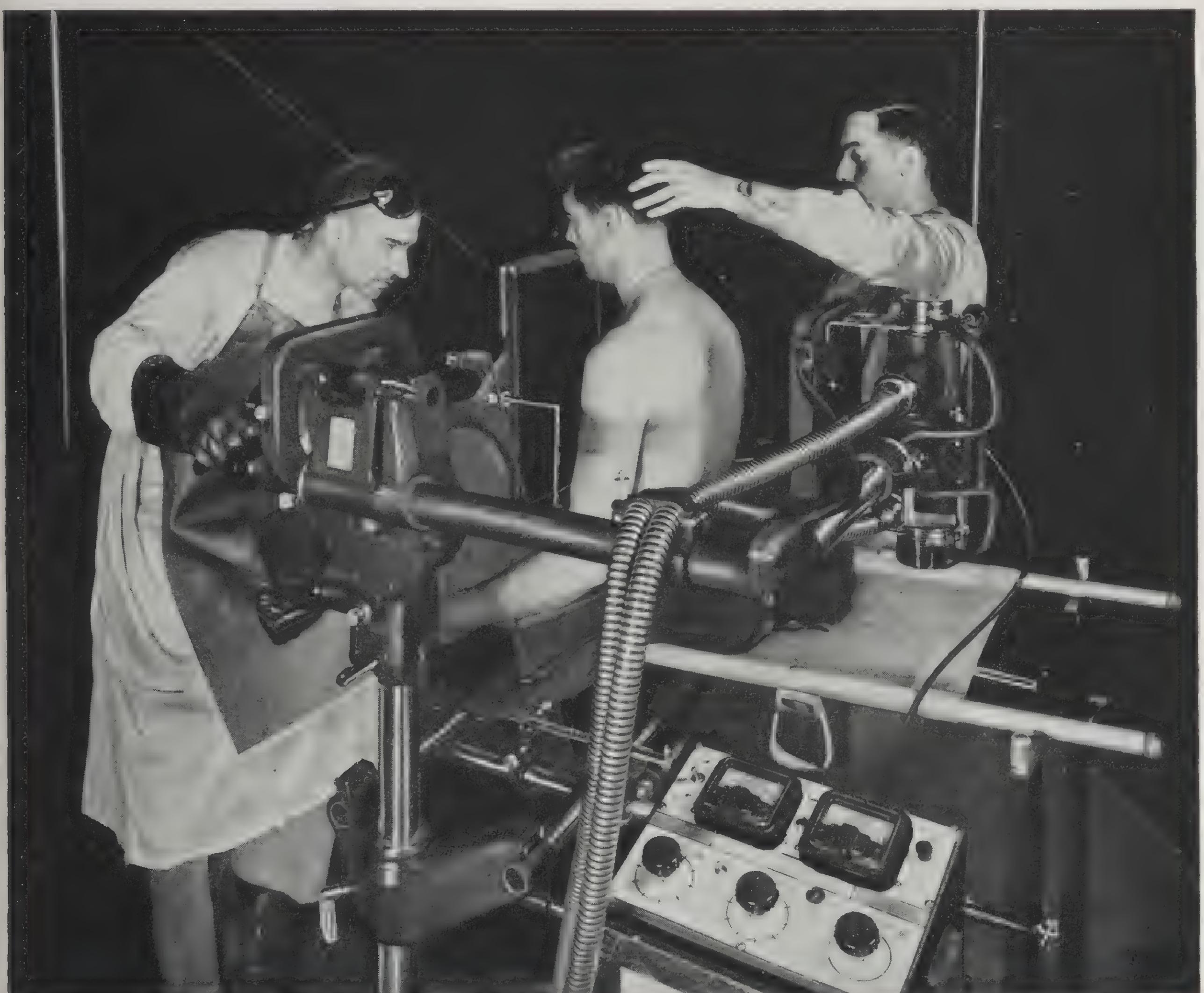


Figure 51. Item 96085 assembled with Item 96145 and in position for sitting roentgenoscopy.

X-3; Item No. 96088 is the control unit chest MD X-4; Item No. 96205 is replacement shockproof cables; and Item No. 96209 is replacement X-ray tube. For repair of the unit a spare parts and repair kit, Item No. 96245 is available.

64. MOBILE CHASSIS UNIT, ITEM NO. 96090. It has been designed to convert Item No. 96085 into a mobile unit for use in the wards and at the bedside. (See fig. 56.) It should be of service in the hospitalization section of the mobile surgical hospital, in the evacuation hospital, the general hospital, and the station hospital. A recent model of this item (fig. 56) is provided with wheels of greater diameter and with means of pulling the X-ray machine unit when mounted on it, as well as pushing it; these additional features have been incorporated to facilitate maneuvering the equipment over rough terrain.

65. PROCESSING UNIT, ITEM NO. 96115. a. General. This item has been developed for use in any type of hospital installation. (See fig. 57.) It has been designed as two sections (Item No. 96115), a master chemical section, and an auxiliary wash section (Item No. 96117). When using the master chemical section alone, 30 to 50 large films (depend-

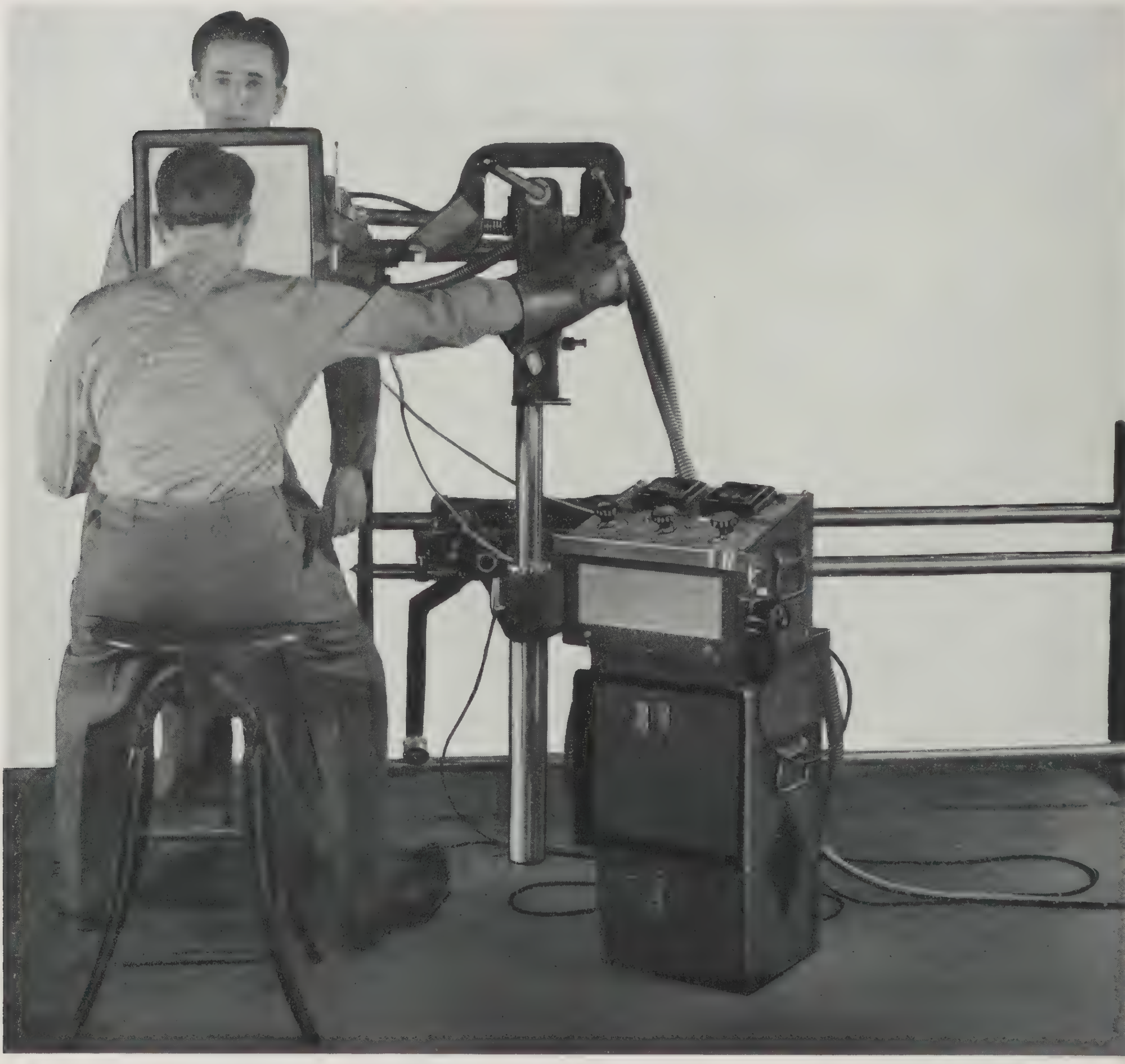


Figure 52. Item 96085 assembled with Item 96145 and in position for standing roentgenoscopy.

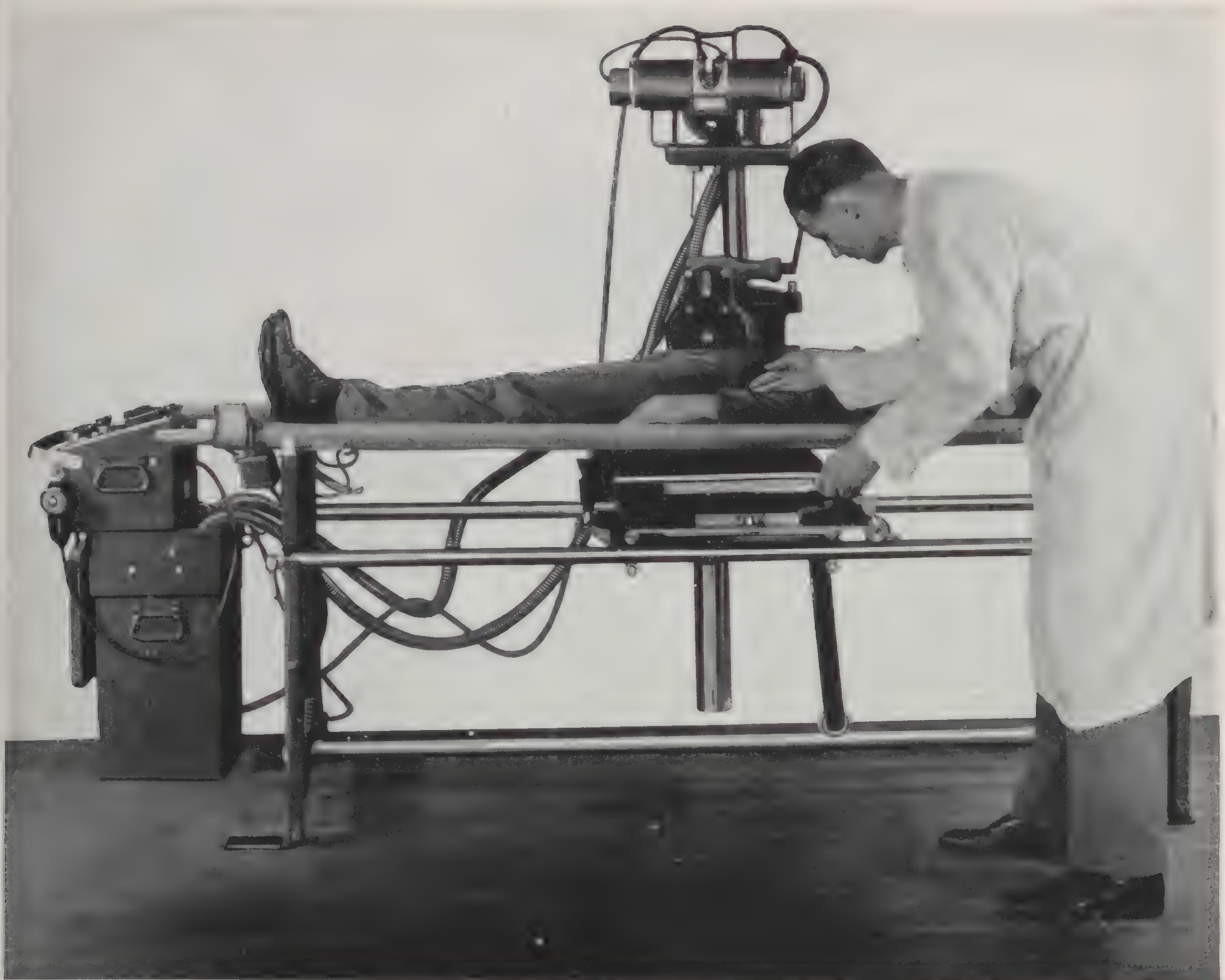


Figure 53. Item 96085 assembled with Item 96145 and Item 96070 for routine roentgenography.

ing upon the availability of community plumbing connections and the temperature of the community water) can be accommodated within an 8-hour period. With the addition of the auxiliary wash section, these accommodations are increased to 200 or more such films. Thus it is believed that the master chemical section alone is practical for smaller station hospitals, for many service command hospitals in times of peace, and for evacuation hospitals in the theater of operations. With the addition of the auxiliary wash section, the unit is considered practical for large station hospitals, for larger corps area hospitals, and for general hospitals as well as induction centers. In a few such locations, it may be necessary to have two such complete installations.

b. The master chemical section (Item No. 96115) consists of a tank compartment and a pedestal or base compartment. The tank compartment has a volume capacity of approximately 50 gallons. Three-gallon, six-gallon, or ten-gallon insert may be accommodated in it. Ordinarily, when this section is to be used alone, the insert tanks should be of 3-gallon (for developer) and 6-gallon (for the fixing bath) capacities. Two 10-gallon insert tanks for developer may be used when the auxiliary wash section is adapted. The pedestal or base compartment contains a water-circulator unit, a refrigerator unit, a heating unit, a mixing chamber, and a thermostatic regulator. The unit is assembled by simply setting the tank compartment upon the pedestal compartment and connecting three water couplings, which can be connected without need of tools. The electrical supply should be 115 volts, 50–60 cycle, single-phase. It might be provided by community supply lines or by means of a portable gasoline electrical generator unit such as item No. 99600. When the water-circulator pump alone is operating, the electrical load is approximately

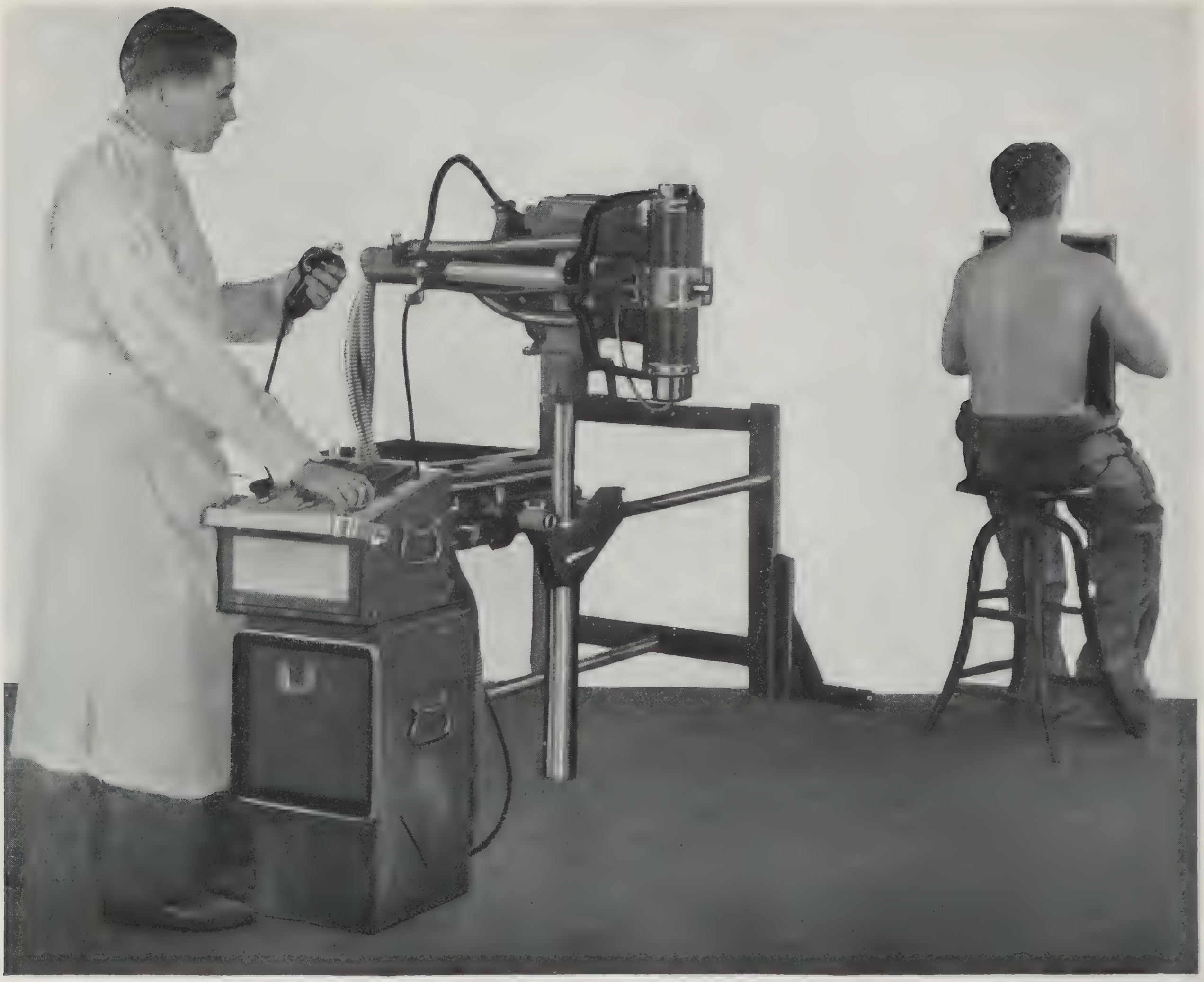


Figure 54. Item 96085 assembled with Item 96145. Adapted for 6-foot vertical chest studies.

100 watts; when the cooling unit is operating with the circulator, the load is increased to approximately 700 watts, while with the heater unit it may amount to as much as approximately 1,300 watts. It was not possible to obtain dual regulator switches at the time when the first of these units were constructed. Therefore, their function is such that either the refrigerator unit or the heater unit operates at all times. To counteract this adverse feature, a triple switch was incorporated in a second group. This triple switch is located in the lower right-hand corner of the front of the pedestal compartment. One switch is intended to open the entire electrical circuits; a second switch controls the heater unit alone and should serve in warm weather to prevent heating when the temperature of the water bath is reduced to 65° F.; the third switch is intended to open the refrigerator circuit alone and should serve in cold weather to prevent cooling of the wash water after bringing the temperature to 71° F. The refrigeration unit has a capacity of 4,000 Btu per hour. The heating unit has a capacity of 3,000 Btu per hour. These limitations must be respected with consideration as to the volume of water which might be allowed to flow through the unit, in the case of community water connections. If the temperature of the community water supply is excessive—above 90° F., or below 40° F. (as can be expected in climates of extreme temperatures and where the piping is close to the surface of the ground)—the rate of fresh water supply must be more limited than where the temperatures are within the ideal range of 60° to 70° F. For these reasons a calibrated inflow valve has been provided. This will be found in the lower left anterior corner of the pedestal compartment. The calibrated values represent 50 percent of the maximum water pressure estimates. Settings are indicated for various temperatures of the community water.

This valve must be adjusted in accordance with the conditions of the day. The temperature of the community water might be checked by drawing water from any spigot though this should not be necessary. It should be practical merely to note whether the heating or cooling unit can accommodate the volumes admitted. The water pump can accommodate only 20 to 25 gallons per hour. In case of inflow at a rate greater than this, recirculation of the water is opposed and the incoming water will flow into the master tank both by way of the normal inflow stem and also by way of the circulating standpipe, thereby completely inhibiting recirculation and effective heating or cooling of the wash water.

c. The auxiliary wash section (Item No. 96117). It consists of two compartments: a tank compartment which is identical in dimensions with those of the master chemical tank described above, and a pedestal compartment. The tank compartment contains two baffles to provide for a cascade type of washing, as shown in figure 58. A precooling system is packed in the pedestal compartment. When in use, the precooling coils are suspended in the tank of the master chemical section. Appropriate connections are made to the incoming water supply attaching it to the furtherest-to-the-left compartment of the auxiliary wash section. It will be noted that separate inflow valves are provided for the auxiliary wash tank and the master chemical tank. These provide for individual rates of water flow through the two tanks. The temperature of the water in the auxiliary wash tank is regulated merely by the temperature exchange from the circulating water of the master chemical section. This is practical because the temperature of the wash tank may be as low as 40° F., or as high as 80° F.,—not necessarily within the temperature range of 60° to 70° as required for the chemical solutions. Circulation and volume of fresh water flow are the more important requirements as far as the wash section is concerned.

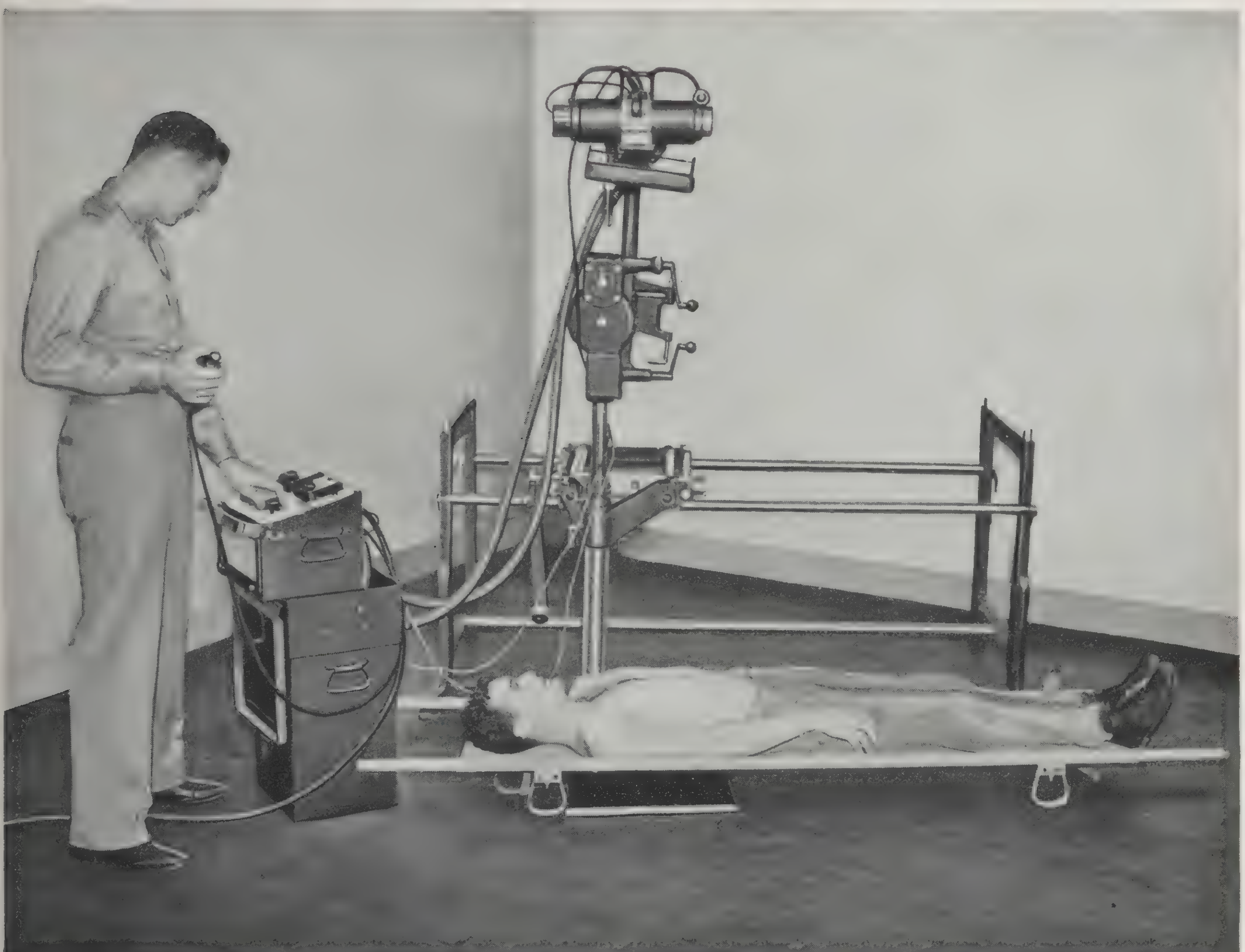


Figure 55. Item 96085 assembled with Item 96145. Adapted for 6-foot horizontal chest studies.

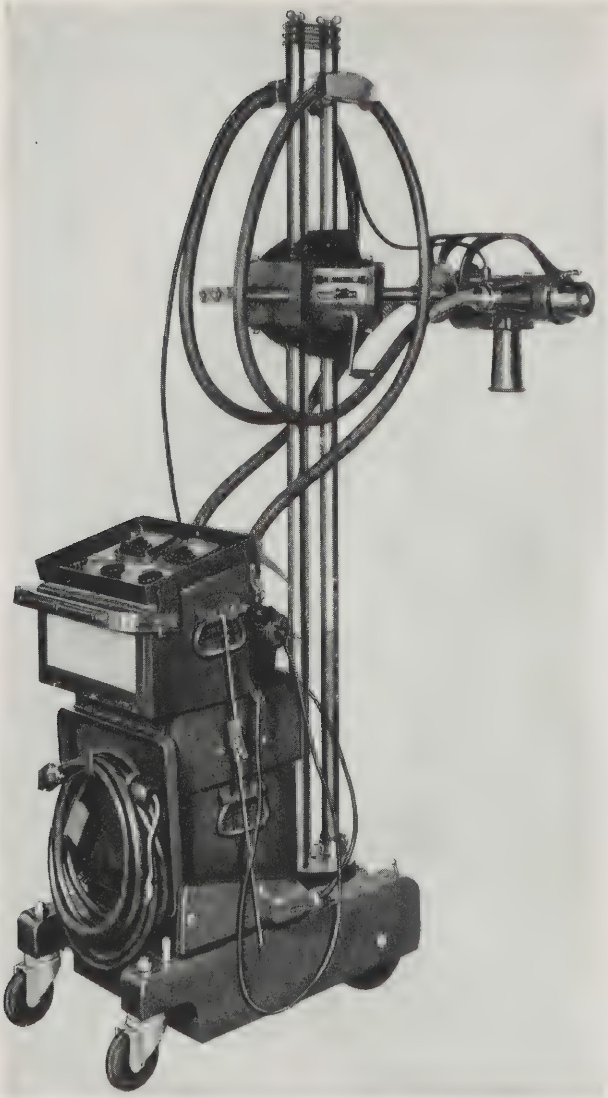


Figure 56(a). Item 96085 assembled with Item 96090 showing adaptation as a mobile X-ray machine unit.

d. Portability. Both sections of the processing unit are composed of two compartments. This provision is for the sake of portability, making the unit practical both for permanent installations and for use in the field. In case of necessity it can be carried in parts to a location where activities may require it. The heating and cooling units as well as the precooler are self-contained. All connections can be made by hand.

66. X-RAY TABLE UNIT, ITEM NO. 96145. a. General. This item is a portable roentgenoscopic and roentgenographic table unit. It is considered practical for usage in any type of hospital installation, though for mountainous terrain or where transportation difficulties require the minimum of bulk and weight, Item No. 96215 may be preferable. It is anticipated that in the motorized evacuation hospital or in the mobile surgical hospital it will be set up for roentgenoscopy. (See fig. 59.)

b. Components. Essentially, this unit is composed of two fabricated steel end-pieces, three rails (each composed of three sections), a horizontal carriage, and a **C**-shaped supporting arm for accommodation of the X-ray tube unit and also of the fluoroscopic screen. These component parts and their assembly are shown in Fig. 60. Detailed instructions covering the packing arrangement of these parts in the field chest and the means of assembly of the unit are given in the pamphlet which accompanies each

Figure 56(b). Item 96090-10. Chassis for field use.

Figure 57. Item 96115, Processing Unit and 96117, auxiliary wash tank.

unit, and also in instruction sheets which can be found on the inside of the lid of the field chests. The reinforcing bolts used with the rails should be clamped tightly when assembling the table chassis. Otherwise, it is important that all clamps and boltings be tightened with finger pressure rather than with hand or arm strength. Engraved captions can be found in various locations on the C-shaped member as well as on the horizontal carriage. It is important to heed these captions, particularly the ones pertaining to releasing the clamps for fixation of the telescoping vertical member of the C-shaped arm. Two fixation clamps have been provided for this member. One of these clamps resists rotation of the telescopic portion while the other resists vertical movement of it. Unless these clamps are released before attempting either of the movements, they will soon become unserviceable. Their reinforcement is important only during foreign body localizations.

c. Adjustments. The C-shaped arm may be adjusted in several ways:

(1) The X-ray tube and fluoroscopic screen may be positioned so as to provide for horizontal roentgenoscopy, with an allowance of vertical shifting through a range of 16 inches.

(2) They may be positioned so as to provide for vertical roentgenoscopy, the patient being in the sitting position.

(3) They may be positioned to one end of the table

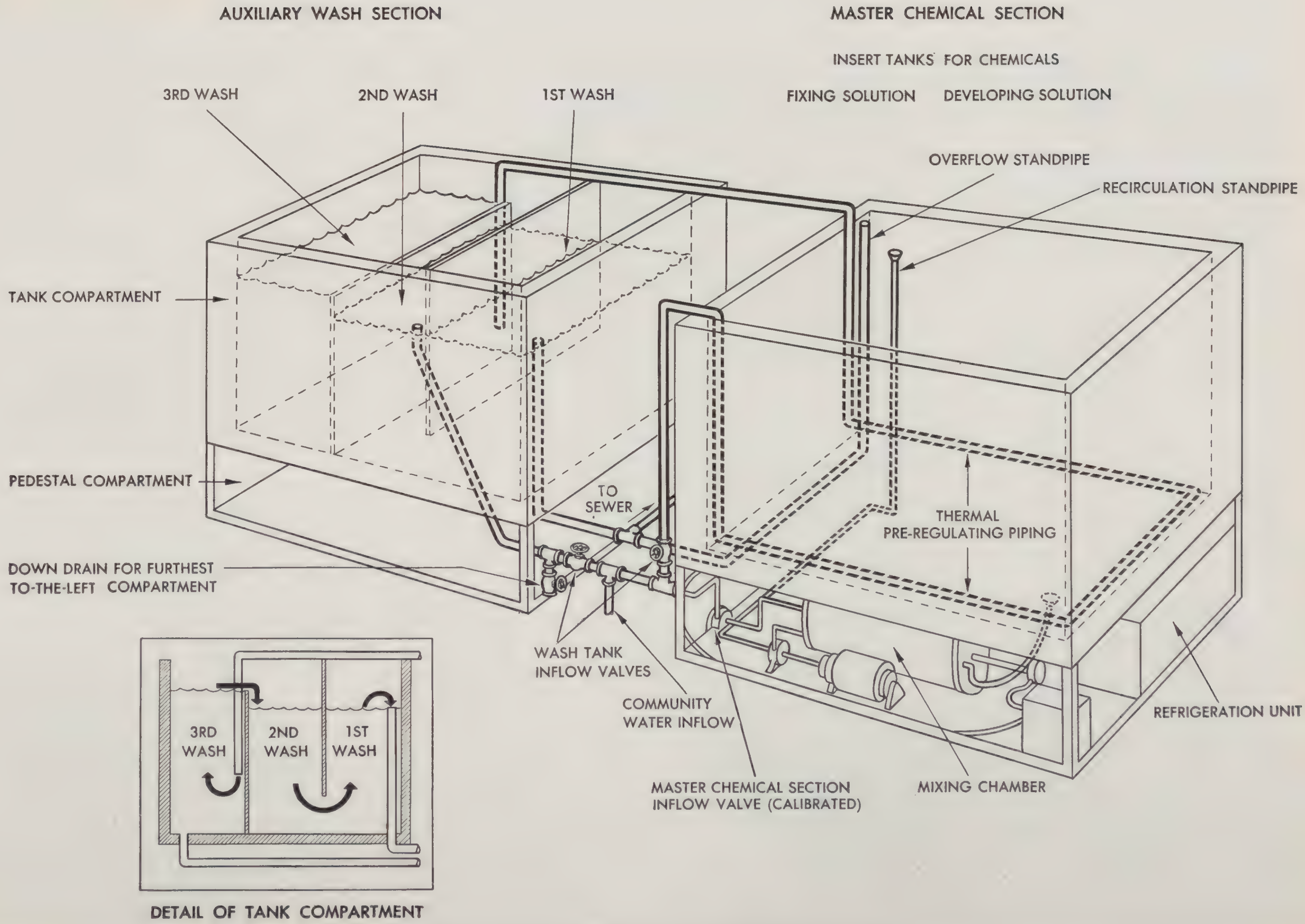


Figure 58. Details of processing unit and auxiliary wash tank.

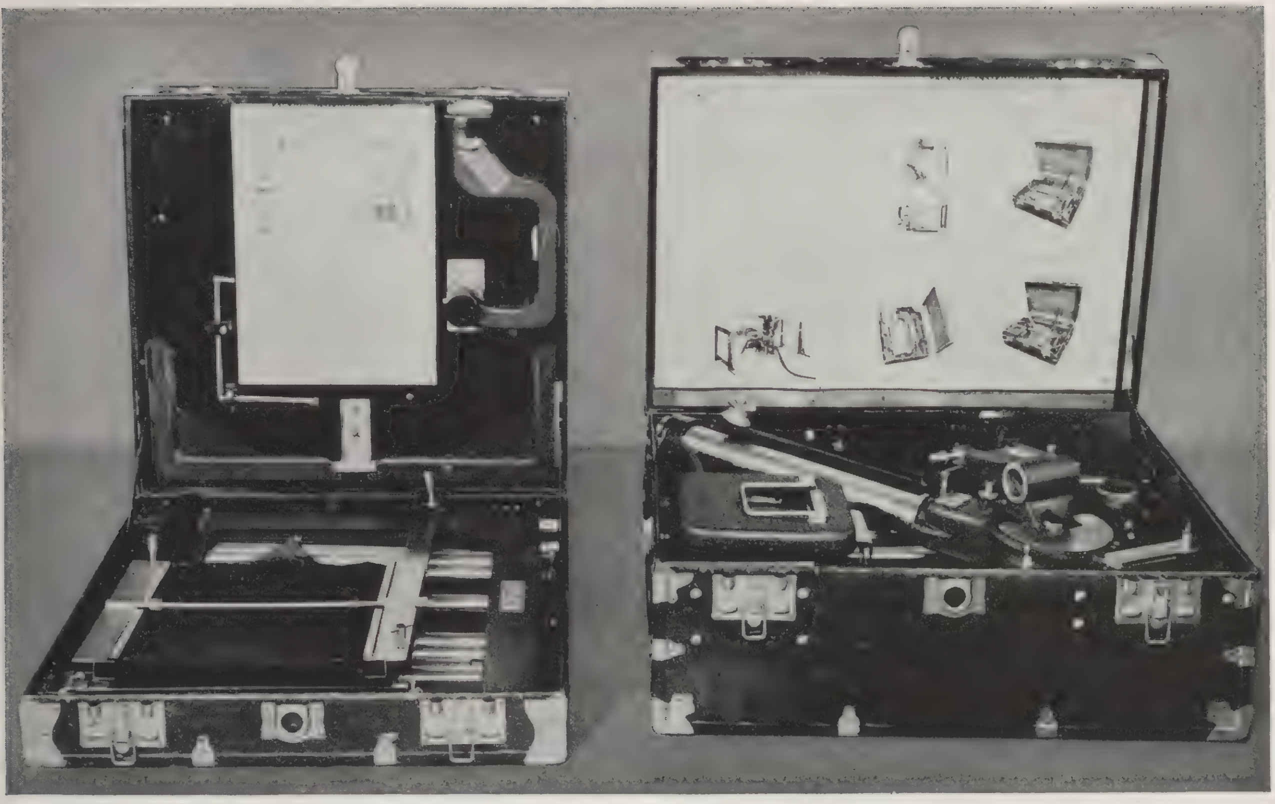


Figure 59. Item 96145, field X-ray table. Packed in chests.

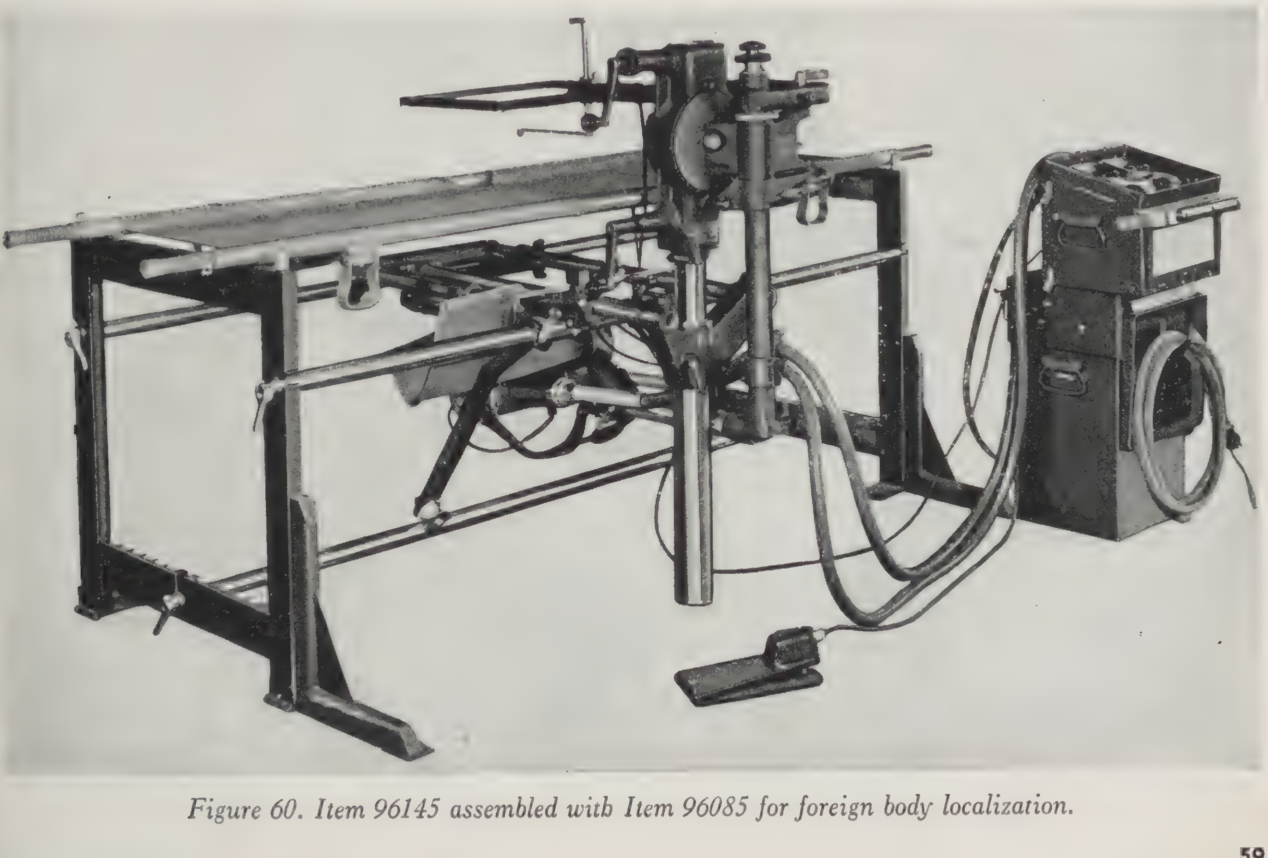


Figure 60. Item 96145 assembled with Item 96085 for foreign body localization.

chassis so as to provide for standing roentgenoscopy.

(4) The tube housing itself may be rotated to a position so as to provide for chest studies with focal film distances as great or greater than 6 feet.

(5) In the position for conventional horizontal roentgenography, the tube housing may be raised or lowered so as to provide focal film distances varying from 29 inches to as much as 45 inches, the patient lying on a litter at the table-top level.

(6) The X-ray tube may be rotated in the horizontal plane so as to provide for chest studies of focal film distances as great as 6 feet, the patient lying upon a litter placed upon the floor.

d. Foreign body localization. As described in chapter 12, two simple auxiliary parts are provided with this unit for adaptation of it to a simple roentgenoscopic method of foreign body localization.

67. DARKROOM TENT, ITEM NO. 96175. a. General. The tent has been designed for usage particularly at mobile hospitals where it is expected that it will be needed both with the mobile operating section and with the hospitalization section. Its design is such that it can be erected indoors in any room (8 by 10 feet in area and 8 feet in height) as well as within a tent or dugout or by itself, in the open. It is therefore quickly adaptable for use in a temporary building or any building taken over for service as an evacuation hospital. It may even serve a purpose at a general hospital, though at this installation it is more likely that substantial darkroom construction will be had. Its design includes a two-way adaptation for roentgenoscopy and/or for film processing. It provides for a quick changeover where lightproof conditions are essential. When erected on the outside, very sturdy support of it may be accomplished by weighting apron with turf, or rocks, etc. Additional support may be provided by utilizing auxiliary guy ropes. The guy ropes are not actually included with this item but eyelets have been provided in eaves which extend from the top sides of the tent. It should not be necessary to use these guy rope supports when the tent is erected within another tent or within a room or dugout.

b. Assembly. Detailed instructions as to assembly of this tent are appended to the inside of the lid of the chest which accommodates the frame support of the tent. As indicated, assembly of the roof frame should first be accomplished, the outer tentage being placed upon this frame so that the end and sides of it are thrown uppermost. The vertical members are then adjusted to each of the four corners so that they project toward the center of the area covered by the tent. The roof frame should then be elevated by lifting each of the four vertical members. The lower horizontal members should then be fixed and the tiller rope attachments applied and tightened. The sides of the outer tentage should then be lowered and the inner curtain and auxiliary drapes adjusted. The fan for forced ventilation should then be installed in the posterior end gable. This should be inclosed by the zipper to provide for light tightness. When used for roentgenoscopy, the inner curtain should be set forward (the auxiliary drapes being folded), and the zipper of this curtain should be opened so that with the door drapes extended, it will be possible to enter the passageway head first without lifting the drapes. For film processing, the inner curtain should be set back (20 inches) and the auxiliary drapes should be extended so as to provide a labyrinth. It is not practical to set up equipment for both roentgenoscopy and film processing in a single tent. These two adaptations are shown in figures 61 and 62.

68. X-RAY MACHINE AND TABLE UNIT, ITEM NO. 96215. a. General. This unit has been designed primarily for horizontal roentgenoscopy, horizontal roentgenography and roentgenoscopic localization of foreign bodies. (See figs. 63 and 64.) The equipment is so designed that it can be packed into three lightweight chests for ease in transportation across difficult terrain. The packing arrangement is ingeniously provided for in order to accommodate all the component parts of the equipment. To simplify assembly printed identifications and color codes are on the parts. The table is so developed that it may be utilized in conjunction with Item No. 96085. The unit consists of the table component, shockproof head and supporting hanger, control, and automatic protective and auxiliary devices. A spare parts compartment for tools and miscellaneous parts are provided in the control unit. A spare tube is also provided as a component of the unit. For roentgenoscopy and foreign body localization, a fluoroscopic screen, depth scale marker and localization dial together with necessary accessories are included. In the event it is desired to accomplish roentgenoscopy without the field tent a daylight hood may be attached to the fluoroscopic screen staging. In addition, a wafer grid accompanies the unit and normally it is located in a slot beneath the fluoroscopic screen.

b. Components. The generating circuit of the unit may be connected to 100–130 or 200–240 volts, 50–60 cycle, a-c. (See par. 53.) The control is compact and it contains all the features incorporated into Item No. 96085 with modifications and refinements. (See par. 80.) The shockproof head includes the tube, high tension transformer, and filament transformer immersed in oil. This arrangement obviates the necessity for shockproof cables. Incorporated within the head is the oil impeller and air circulating motors. In addition, it permits the placement of the shockproof components into one insulated head. The X-ray tube of this unit is accommodated in a separate compartment within

Figure 61. Item 96175, field darkroom tent.

Figure 62. Item 96175. The adjustable inner curtain set back with auxiliary drapes extending to provide the labyrinth as needed when the tent is to be used for film processing.

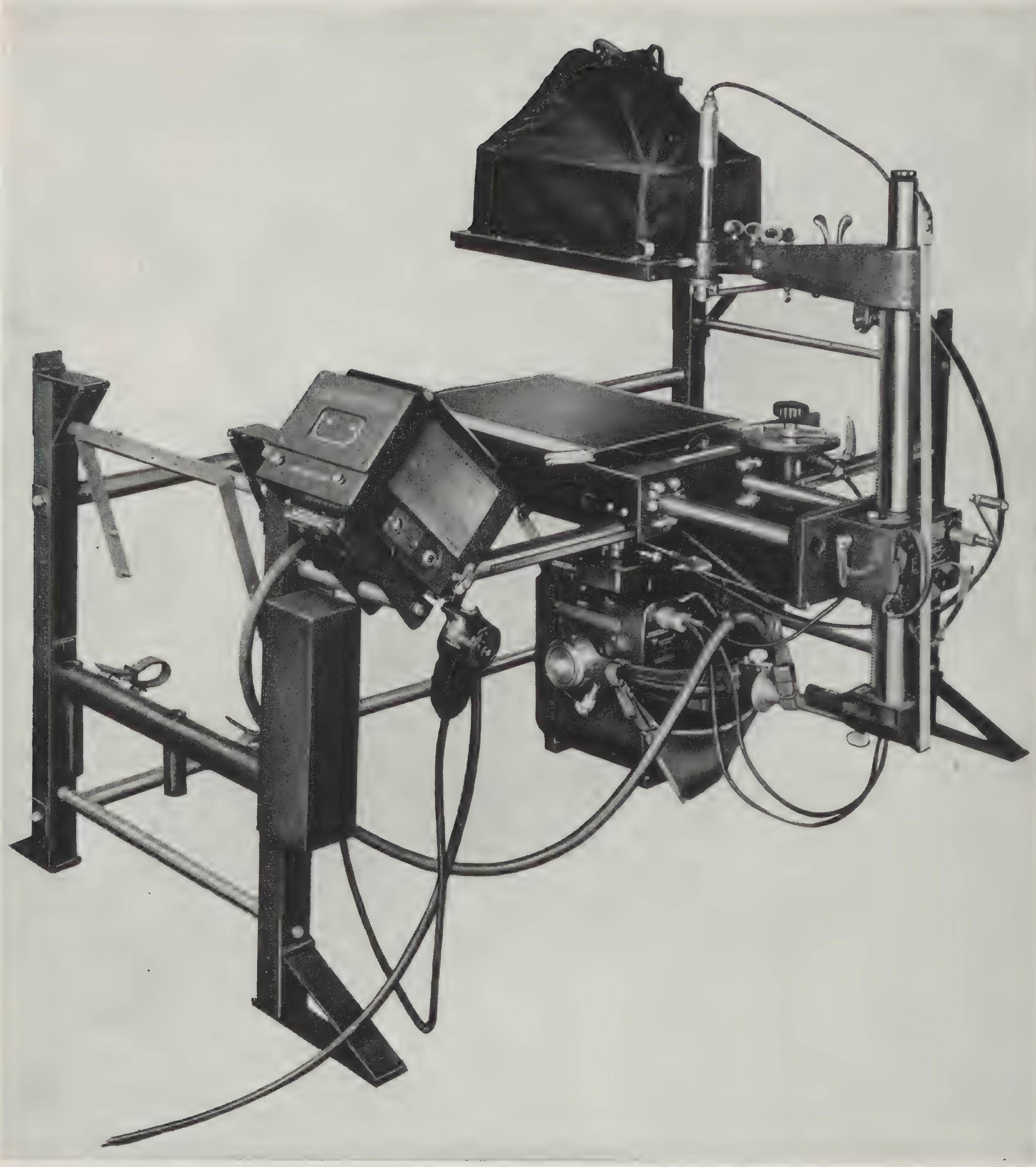


Figure 63. Item 96215, combination X-ray machine and table assembled for foreign body localization and roentgenoscopy.

the shockproof head so that easy exchange of it can be accomplished without the usual difficulties concerned with removing and replacing transformer oil. Instructions for this procedure are found in the manual accompanying the unit. The table portion of the unit is assembled with the use of the tools provided and in accordance with instructions printed on the inside of the lids of the chests. The procedure for foreign body localization as accomplished with Item 96145 pertains also to this item. For roentgenography the table is provided with a cassette lifting device.

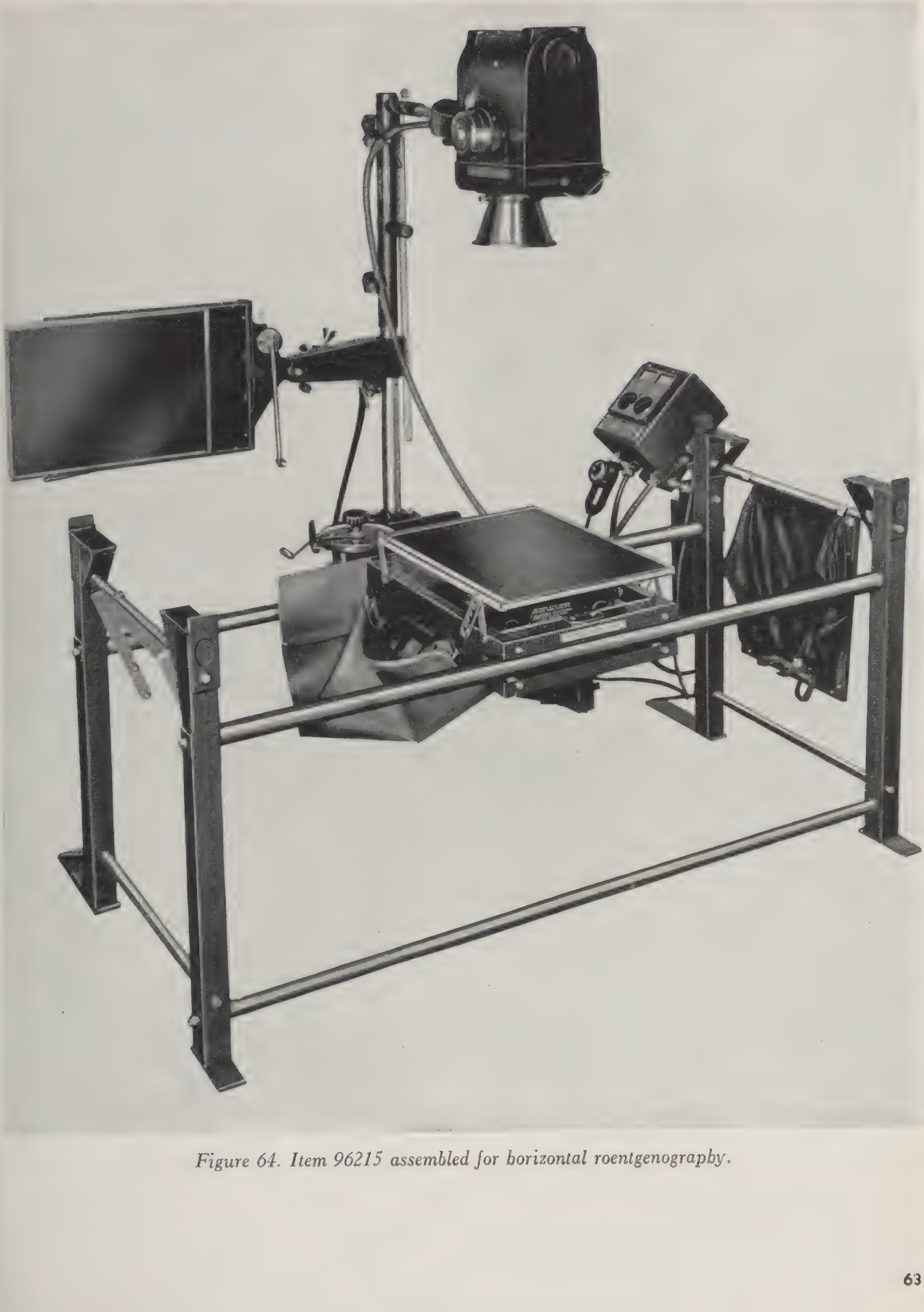


Figure 64. Item 96215 assembled for horizontal roentgenography.

CHAPTER 4

OPERATION AND CARE OF ROENTGEN-RAY EQUIPMENT

SECTION I. HANDLING OF CONTROLS

69. GENERAL. An X-ray unit is similar to any other intricate precision machine and should be handled in a careful, thoughtful manner. Before attempting to operate an X-ray unit for the first time, it is good practice to study and identify the various controls, meters and devices on the panel. A large percentage of the failures of the various parts of X-ray equipment are due to careless or indifferent handling of the controls. The manipulation of switches, line voltage compensators and autotransformer control should be based upon an understanding of their function plus common sense.

70. MAIN SWITCH. The X-ray machine is connected by means of a cable to the main power switch. The modern type of switch is designed to "make" or "break" a circuit in a short period of time, thereby tending to prevent the formation of an arc, which causes burning at the points of contact. The operation of this type of switch usually depends upon a mechanical arrangement, whereby a spring acts in the opening or closing of a circuit. This mechanical arrangement removes the human element and improves the electrical performance of the contact. On the panel of the X-ray machine will be located the main switch which serves to energize the unit. In some designs of X-ray machines, a circuit breaker is incorporated with the main switch. In the event of an overload this circuit breaker serves to trip the main switch and open the circuit.

71. LINE VOLTAGE INDICATOR AND COMPENSATOR. Most X-ray machines will have located on the panel (or within the control case—accessible usually from the back of it) a line voltage compensator which is used to compensate for variations in supply voltage to the autotransformer. These changes may be shown by the line voltage indicator, V_2, figure 17. (See par. 29.) Not all machines will contain these two components. In Item No. 96085 and Item No. 96215, neither are located on the control but provision is made for compensation within the unit.

72. PREREADING KILOVOLT METER. The kilovolt meter is usually located on the panel although some machines such as mobile units may dispense with it entirely and refer to a calibrated scale at the autotransformer controls. The meter, when present, is always an a-c voltmeter and may be calibrated in arbitrary values or in kvp values as determined by the manufacturer. When the machine is functioning properly, the meter will indicate when the main switch is closed.

73. AUTOTRANSFORMER CONTROLS. Voltage applied to the primary of the high tension transformer is regulated by the autotransformer controls. Usually this is accomplished by a major and minor selector located on the panel. Some units may have only one control. Any increase or decrease in the kilovoltage desired, as indicated in the kilovolt meter, V_3, figure 17, is accomplished by the manipulation of these controls. The position of the autotransformer controls, and likewise the line voltage compensator must never be changed when the primary of the high tension transformer is energized or when X-rays are being produced. The reason for this is that changing of controls under load would cause an arcing with eventual destruction of the contacts. This arcing may be of such intensity as to pit or actually weld the contacts in a fixed position. Mere pittings will increase the contact resistance thereby altering the load performance of the unit.

74. FILAMENT REGULATOR. The filament regulator may be either a choke coil or a rheostat. Manipulations of this control cause a change in the filament current indicator which may be either an ammeter or voltmeter. In case of the ammeter the scale may be either true or prereading. If a voltmeter is used (Item No. 96085—96215) the scale is arbitrary. The filament indicator is always an a-c instrument. The filament regulator may be adjusted while the tube is producing X-rays. Most failures of filaments of X-ray tubes are due to excessive currents flowing in the filament. Before the X-ray machine is energized, the filament regulator should be at its lowest setting unless presetting values are known as indicated by the above mentioned meter.

75. MILLIAMMETER. In shockproof equipment, the milliammeter is mounted on the control panel. In the case of nonshockproof equipment where the milliammeter is at high potential in the high tension circuit, it will be located suspended from the ceiling on an insulated support. This meter will be a d-c instrument. If, in the case of full-wave equipment, a milliammeter is found on the panel (connected between the center tap of the transformer and ground) it will be an a-c instrument unless a rectifying circuit such as a copper oxide rectifier or thermionic valve is used to transform the alternating-current into direct-current. In this case the meter will be d-c. It must be emphasized that the milliammeter on all self-rectified and half-wave units is d-c. Some stationary units may have mounted on the panel a milliampere-second meter (Ma.S) or ballistic meter. If this meter is used with nonshockproof equipment and is at high potential in the secondary circuit it must be located in the overhead aerial system. In the case of four-valve, full-wave units, a valve filament meter may be provided. This meter is used to indicate the filament current supplied to the valve-tube filaments.

76. FOCAL SPOT SELECTOR. The focal spot selector will be present only in the event that the equipment is designed to utilize a double focal spot tube, which has incorporated within it a means of reducing the filament current when changing from the large to the small filament, that is, the focal spot selector may be located on the panel or attached directly to cathode portion of the tube. It might also be located on the cathode side of the aerial overhead system of nonshockproof equipment. With some units, focal spot selection is accomplished automatically within the control depending upon the range of milliamperage selected. A very common error in the handling of X-ray machine units which have a double focal spot tube is to energize the small focal spot beyond its rating. This is counteracted in some machines by electrical safety devices. However, not all types of machines are provided with this protective feature.

77. TIMERS. The length of X-ray exposure is controlled by the timer. The hand timer will usually be suspended from a bracket at the side of the control. The synchronous motor or impulse timer may be incorporated into the structure of the control stand. In some instances the impulse timer is a separate component of the unit.

78. AUXILIARY CONTROLS. As the term indicates, auxiliary controls refer to any devices designed to facilitate the accomplishment of high quality roentgenography. Included are: remote control switches for the Potter Bucky diaphragm, stereoscopic shifting mechanisms, casette changer controls, and other controls that may be added depending upon the design of the equipment.

79. HANDLING CONTROLS OF ITEM NO. 96085. Item No. 96085 consists of three main components: the transformer, X-ray tube, and control. The control is the central means of controlling and adjusting the output of the machine. It also acts as the central location for the connection and coordination of the various circuits. On the top of the control unit is an etched panel containing various identifications and instructions. The controls are alphabetically identified.

a. "Main" Switch "*A*" serves to open and close both sides of the main line circuit to the autotransformer and serves to energize the control.

b."The Radiographic-Fluoroscopic" Safety Switch "*B*" when adjusted to the fluoroscopic side disconnects the hand timer and connects the foot switch and the tube current is indicated on the low scale "*K*" of the milliammeter. When the switch is set to the radiographic side the hand timer is in the circuit and the foot switch is disconnected, and the tube current is indicated on the high scale "*K*" of the milliammeter.

c."Kilovolt" Selector Switches "*C*" and "*D*" are the major and minor controls respectively of the autotransformer.

d. "Kilovolts" Meter "*E*," indicates the kilovoltage applied to the X-ray tube. When this meter is read under load it indicates the useful kilovoltage.

e. "Check Filament" Switch "*F*" when placed in the forward position serves to connect the upper scale "*G*" of the kilovolt meter. This scale will arbitrarily indicate the presetting of the filament current for a given milliamperage.

f. "Milliamperage" Regulator "*H*" serves to regulate the filament current of the X-ray tube as indicated on the filament scale "*G*" of the meter "*E*."

g. Circuit "Breaker" "J. " The knob "*J*" serves to close the operating contacts of the circuit breaker which acts as a safety device in the primary circuit of the high tension transformer, in the event of an overload. The contacts are closed when the button is pushed down and open when the button is up.

h. "Milliammeter" "K." When the radiographic-fluoroscopic safety switch "*B*" is in the radiographic position, the upper scale of the milliammeter should be read. When the switch is in the fluoroscopic position, the lower scale of the milliammeter is indicating the tube current.

80. HANDLING CONTROLS ITEM NO. 96215. The control panel of Item No. 96215 is inscribed alphabetically in order to identify the controls.

a. "Main" Switch "*A*" serves to open and close the main line circuit to the autotransformer and energizes the control. The main switch is capable

of adjustment in three positions: "Off," "Low," and "High." With the main switch in the low position the lowest kilovoltage available is approximately 40 kvp. With the switch in the high position the maximum kilovoltage available is slightly above 80 kvp.

b. "Radiographic-Fluoroscopic" Safety Switch "B." This switch serves to change the unit from fluoroscopy to radiography, similar to Item No. 96085. It also changes the calibration of the circuit breaker from an approximate tripping value of 7 ma for roentgenoscopy to a value of 18 ma for roentgenography.

c. "Kilovolts" Selector "*C*" controls the voltage applied to the primary of the high tension transformer. It consists of one knob and the voltage range is determined by the position of the main switch.

d. "Kilovolts" Meter "D." The scale of this meter indicates the kilovoltage applied to the X-ray tube under load.

e. "Check Filament" Switch "E." With the switch at its normal position the kilovolt meter scale is utilized. When the switch is depressed the upper scale "*F*" of the kilovolt meter arbitrarily indicates the current supplied to the filament of the X-ray tube.

f. "Filament Control" "G." The filament control consists of a rheostat so provided that the milliamperage may be adjusted to any value up to 15 ma.

g. Circuit "Breaker" and Breaker Reset "H." When the circuit breaker which is activated directly into the high tension circuit is overloaded and the circuit is opened thereby, depressing the breaker reset "*H*" will restore the action of the breaker to the circuit.

h. "Milliammeter" "J." This meter indicates the X-ray tube current when the unit is energized.

SECTION II. CALIBRATION

81. GENERAL. There are certain performance characteristics which must be considered individual to any one unit. The design and construction features of high tension transformers are not consistent. To a lesser degree, this also holds true for filament transformers and for autotransformers. Even when constructed by any one company and regardless of large scale production, these variations prevail. Of course the differences in performances are considerably greater when the product of one manufacturer is compared with that of another. There are, therefore, a number of questions which even an expert X-ray technician will ask when faced with strange equipment. Certain questions would indicate intelligence on his part rather than ignorance. For instance, he should inquire as to calibrated settings concerned with kilovoltage values in relation to usable milliamperage loads; he is entitled to know the radius of the particular grid; what its ratio is and therefore what milliamperage-second requirement is necessary when using the grid as compared with roentgenographic factors without the use of it; and he is entitled to know the speed and intensification factor of the various types of intensifying screens.

82. CURRENT CALIBRATION. Since the current through an X-ray tube is determined by the heat of the filament and this in turn is dependent upon the current through the filament, it is practical to predetermine the filament current required for any desired milliamperage. Since the current through the filament may vary with different settings of the autotransformer, it may be necessary that a filament current reading be determined for selected milliamperage values in relation to the various kilovoltage values. If the filament current has been predetermined it will be unnecessary to make test exposures and repeated adjustments of the filament control. The machine and especially the X-ray tube must not be subjected to unnecessary use. The machine should be calibrated only when it is moved to a new position, when a new functional component is added to the machine, such as a transformer, cable, autotransformer, etc., and otherwise about once each week for a spot checking on the operating characteristics. To obtain a current calibration of a unit it is necessary to adjust the filament regulator until the desired milliamperage is indicated. At this point the filament current value is recorded. The table shown in figure 65 is a sample of a filament calibration within the operating kilovoltage range.

83. CURRENT LIMITATION, ITEM NO. 96085. Adjacent to the line adjustment on the panel of the Field Unit is the Fluoroscopic Limitor Rheostat. Its function is to set a maximum limit of the current through the X-ray tube when the unit is used for roentgenoscopy. This is extremely important in prolonging the life of the tube, especially if the unit is used by more than one person, or if the operator is not familiar with the equipment and has not had considerable experience in roentgenoscopy. The fluoroscopic limitor rheostat should be turned to the extreme left to its lowest position. Then the filament regulator on the control stand is turned slowly toward the right to its maximum position. If the current through the tube, while the machine is set for roentgenoscopy, is greater than 5.5 milliamperes before the filament regulator reaches the maximum position, the strap listed as "X-ray Filament Adjustment," must be changed to a lower setting. If the regulator on control stand is at its maximum position, and the current through the tube is less than 5.5 milliamperes, the fluoroscopic limitor rheostat should be increased slowly until the desired current is obtained. The fluoroscopic limitor rheostat will function only when the radiographic-fluoroscopic switch is in the fluoroscopic position.

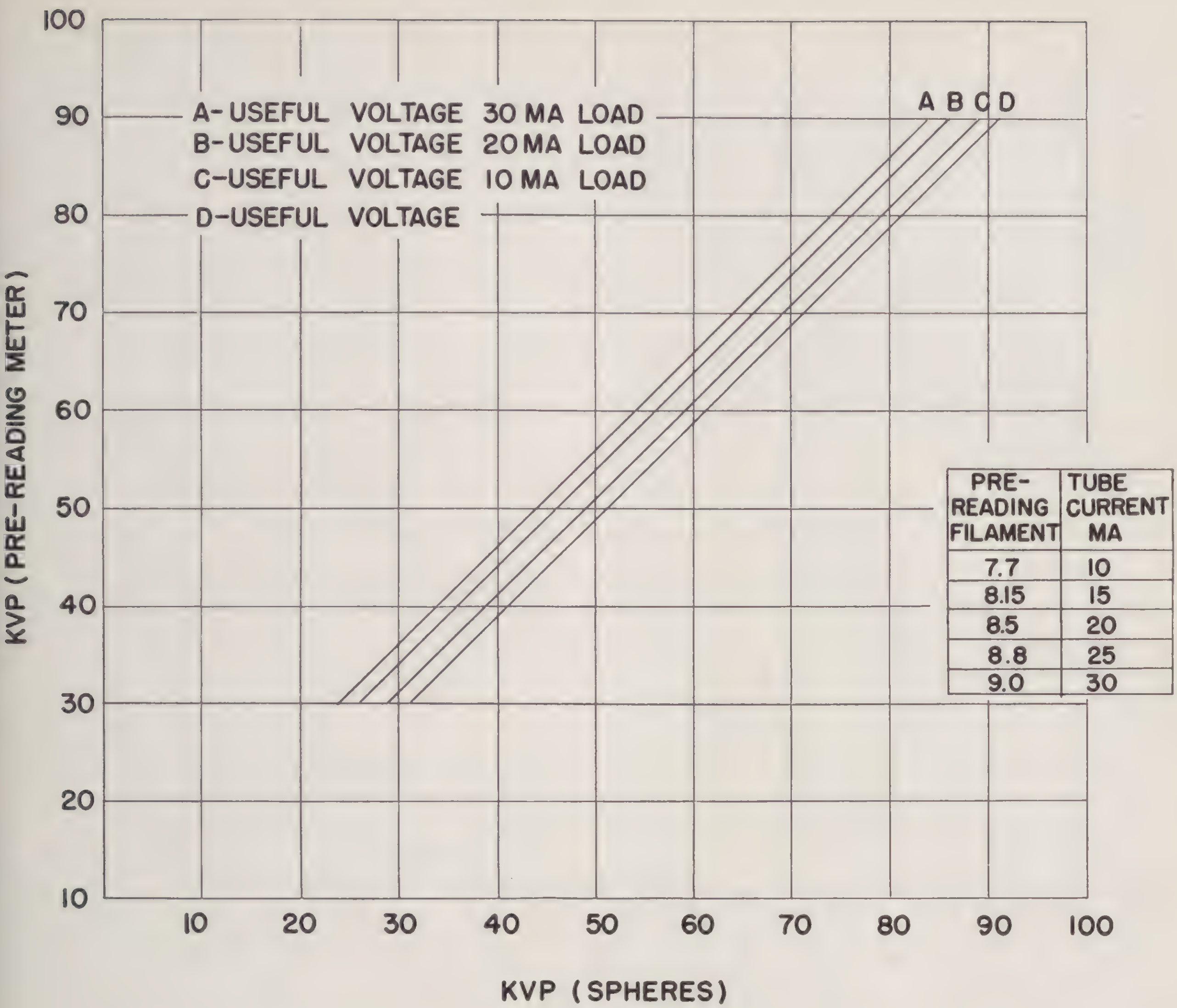


Figure 65. Average kilovoltage calibration for field X-ray units, Item 96085 (10 machines).

When the X-ray filament adjustment strap is in the proper position and the fluoroscopic limitor rheostat has been correctly adjusted the machine will provide for roentgenography and roentgenoscopy; that is, 30 ma, 85 kvp for roentgenography and a maximum of 5.5 ma, 70 to 75 kvp for roentgenoscopy.

84. VOLTAGE CALIBRATION. The kilovoltage impressed across the X-ray tube is indicated by the kilovolt meter. In order to determine the accuracy of the readings a calibration is required. The method commonly employed is by means of sphere gap. There are other methods such as the electrostatic voltmeter, spectrographic analysis, cathode ray oscillographs, and roentgenographic calibrations. When there is no current load in the secondary, the voltage between the terminals of the X-ray tube is described as *no-load voltage.* This voltage (no-load voltage) exists when there is no flow of electrons from filament to target even though there be energization of the high tension transformer. With half-wave rectification it exists during the non-productive half of the cycle. Since, during the non-productive half of the cycle, the X-ray tube in self-rectified circuits acts as a current suppressor, this voltage is called the "inverse voltage." The maximum value of the no-load voltage is very important in the design of the X-ray tube, tube head, shockproof cables, and other components of the high tension circuit. During the productive half of the cycle, there is a voltage drop across the winding of the transformer. The voltage across the tube during the production of X-rays (that is, during half cycles wherein the electrons flow from cathode

to anode) is known as the "useful" voltage. This useful voltage is the prime factor which determines the quality of the X-ray beam. Since the voltage drop in the secondary winding is directly determined by the value of current flowing, it follows that, as the current through the tube is increased, the voltage drop will increase, and the voltage across the X-ray tube will decrease; hence, the importance of knowing the useful kilovoltage values at various current settings. The no-load voltage in self-rectified units is always greater than the voltage under load. In a poorly designed and poorly built high tension transformer this difference may be as high as 20 percent. The prereading kilovolt meter on most machines is not calibrated in terms of useful voltage; instead, the values are usually no-load voltages. Therefore, it is necessary that one determine and know the useful voltage in terms of the no-load voltage. This may be accomplished by connecting two spheres (one movable and one fixed) in parallel with the X-ray tube. When the tube is energized, the movable sphere is approximated to the stationary sphere. At the point where the impressed voltage is sufficient to arc across the gap, a measure of the voltage is obtained from a scale. It can be seen that when the arc occurs there is actually a short-circuit of the high tension transformer. In order to protect the transformer against the excess current drawn and the spheres against pitting, high resistances (at least 1.5 megohms) are placed in series with each sphere. The useful voltage is determined by this method for various milliamperage loads over the kilovoltage range. The procedure is relatively simple with non-shockproof equipment but it is not very easy with shockproof units. With shockproof units one needs a pair of extension sleeves—insulated sleeves that can be inserted into the sockets of the tube head or transformer terminals. The ends of the insulated cables are inserted into the protruding ends of the sleeves. In a self-rectified circuit such as described in figure 26, the maximum peak voltage that would be determined would be the no-load voltage. In order to determine the useful voltage, it is necessary to connect a valve tube in the circuit, as shown in figure 66a. It must be borne in mind that current must flow through the valve tube during the same period of time that current is flowing through the X-ray tube. Therefore, the filaments of both tubes should be connected to a common point. For a high degree of accuracy, it is essential that the temperature of the surrounding atmosphere be considered, and that the barometric pressure be taken into account. For such correction factors, reference to any engineering handbook is suggested. With full-wave rectification (valve-tube) no-load voltages are of unimportance and it is not necessary to include a valve in the sphere gap circuit. The U. S. Army Field Unit is well designed and reasonable duplication by one unit by another can be expected. Figure 65 shows an average kilovoltage calibration for various loads of a group of field units. This curve may be utilized for any field unit without appreciable error. The field unit, Item No. 96085, is so designed that, when the major autotransformer control is placed in position "6" and the minor control is placed in position "4," the prereading kilovolt meter should read "70," if one is to obtain standard results. If the kilovolt meter should read a value greater than "70," the line voltage is greater in value than the setting of the line voltage adjustment, which is located on the panel board of the control stand. This means that, if the line voltage adjustment was set at, for instance, "112," and the kilovolt meter reads greater than "70," with the major control at "6" and the minor control at "4," the adjustment strap should be moved to a higher value. The line voltage adjustment is varied in steps of 8 volts. One should adjust and readjust, if necessary, until the needle is as near to "70" as possible. The largest possible variation should not be greater than 3 scale divisions; if one obtains a reading of "73," place the strap on the next point, and possibly obtain a value of "68," which would be nearer the prescribed value and

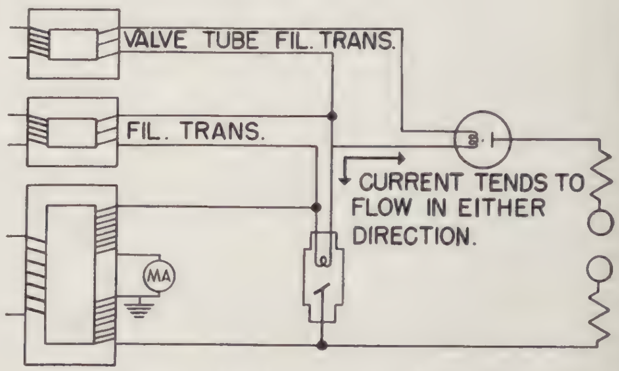


Figure 66(a). Measuring useful voltage.

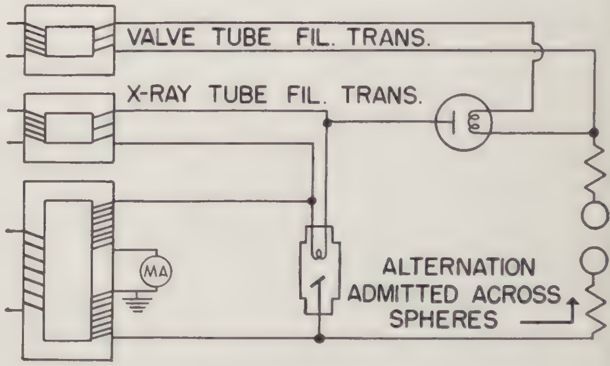


Figure 66(b). Measuring inverse voltage.

therefore a more accurate calibration. To adjust the supply voltage for Item No. 96215 a line voltage compensator is provided on the side of the control unit. The knob "*G*" on the control is set to zero and the main switch "*A*" is set on high (as indicated by the red dot). The switch "*B*" is placed in the radiographic position and knob "*C*" set on button "3." With a key or coin the line adjuster is regulated until the voltmeter "*D*" reads in the red area on the scale. The unit will then be calibrated for line conditions.

85. DIMENSIONS OF EFFECTIVE FOCAL SPOT.

A simple method to determine the dimensions of the effective focal spot is to use a lead diaphragm having a 0.5 mm opening beneath the portal of the X-ray tube, and at one-third the distance between it and a dental film, figure 67. An exposure is made at 60 kvp for 40 ma-secs at 30 cm. An image of the focal spot will appear on the film. Using calipers, measure across the area of uniform density, ignoring the peripheral lesser densities produced by penumbra. With this measurement apply the following formula:

$$\frac{\text{projected dimension}}{2} - \frac{3 \text{ x aperture dimension}}{2} = \text{effective focal spot dimension.}$$

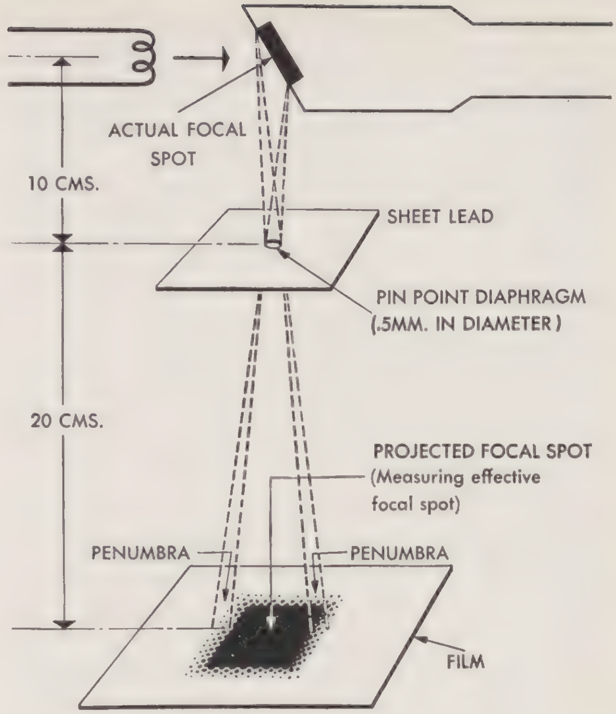


Figure 67. Measuring focal spot.

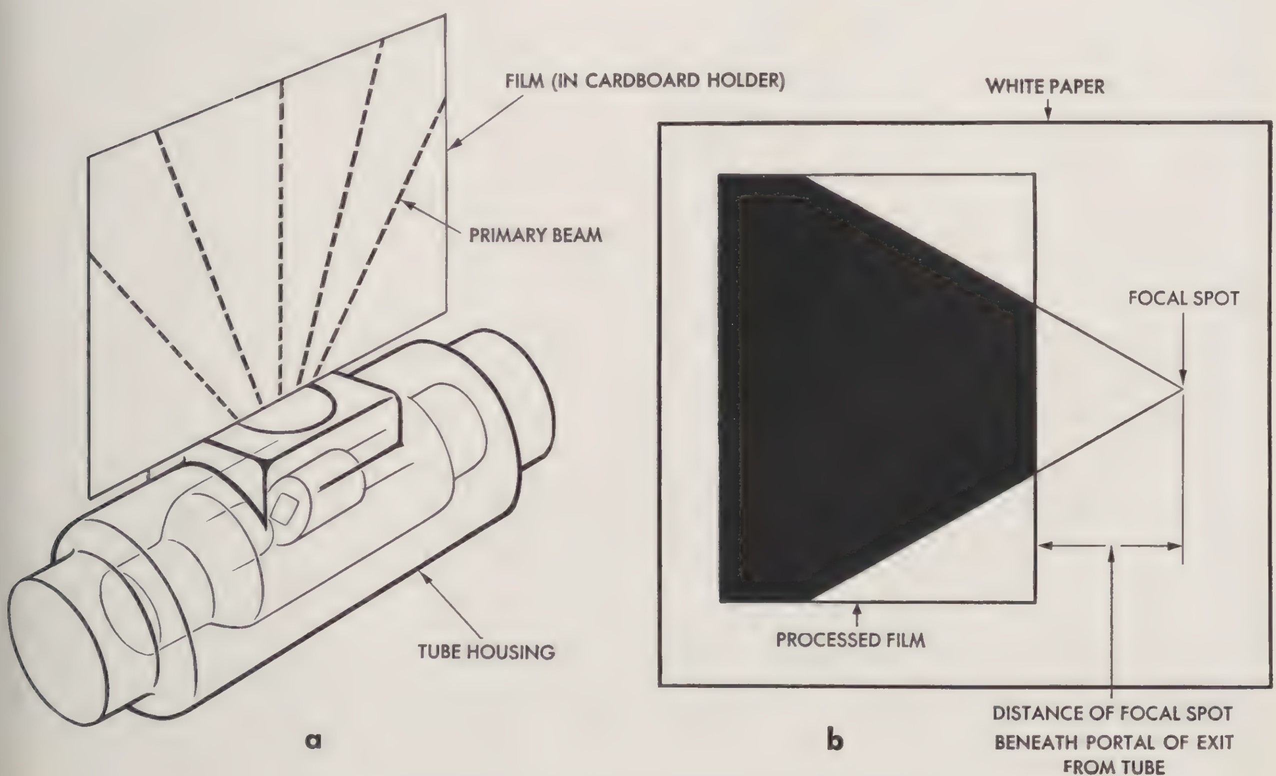


Figure 68(a) and (b). Determination of focal spot level.

86. DETERMINATION OF FOCAL SPOT LEVEL. Occasionally it may be necessary to measure the position of the focal spot of the X-ray tube in relation to the plane of the exit portal of the primary beam. This may be indicated when dealing with foreign body localizations or when trouble by a cut-off in the area of coverage by the primary beam. With modern equipment, the entire tube is likely to be concealed within a tube housing. Should it be necessary to determine the exact location of the focal spot, a simple procedure is to place an 8- by 10-inch film (contained in a cardboard holder) on its side, the middle of it positioned across the exit portal and approximately at right angles to it. (See fig. 68a.) After making an exposure, such as 60 kvp for 40 ma-sec., the film should be processed in the usual manner and then laid upon a white background. By projecting the converging borders of the roentgenographic density produced to the point of their intersection on the film, there will be obtained a fairly accurate measurement of the position of the focal spot beneath the plane of the exit portal. (See fig. 68b.) It should be realized that a slight error will be incurred because of "penumbra." This error will be greater when a large focal spot is used rather than a small one. The penumbra can be identified and eliminated to a considerable extent provided the roentgenographic density is proper.

87. TIMER. Prolonged exposure times may be checked with the use of a reliable stop watch. Exposure of less than 1 second might be checked with the use of a spinning top. This device is simply an X-ray opaque top containing a perforation or notch so that when the top is made to spin, the perforation or notch will rotate in a plane parallel to the film over which it is positioned. If an exposure is made, the X-ray tube being positioned above the top, provided the top be truly X-ray opaque, there will be projected a series of outlines of the perforation or notching. These should indicate the number of pulsations of X-radiation coincident with the pulsations of the high tension current. In the case of full-wave rectification, with a 60-cycle current, there are 120 pulsations per second. In such a case, the number of dots of roentgenographic density indicated by the top test, divided by 120, will indicate the fraction of a second exposure. (See fig. 69.) In the case of half-wave currents, provided the cycle be 60, the divisor should be 60 rather than 120.

88. DETERMINATION OF GRID RADIUS: GRID RATIO. The radius of a grid is usually described on the side of its housing, but it can be determined by positioning the grid beneath the X-ray tube and making a number of exposures at different distances. That distance which serves to project each individual lead strip uniformly (that is, as of uniform thickness) upon the film can be considered to be the grid radius.

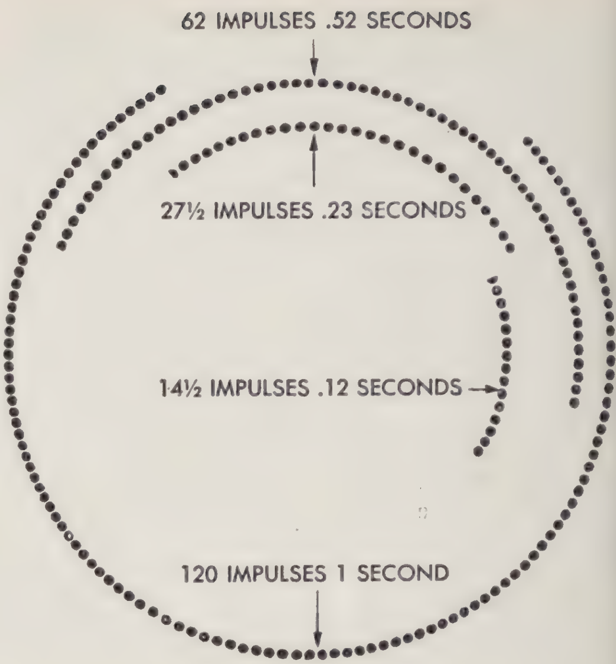


Figure 69. Spinning top for testing timer for accuracy, illustrates testing timer with full-wave rectified unit.

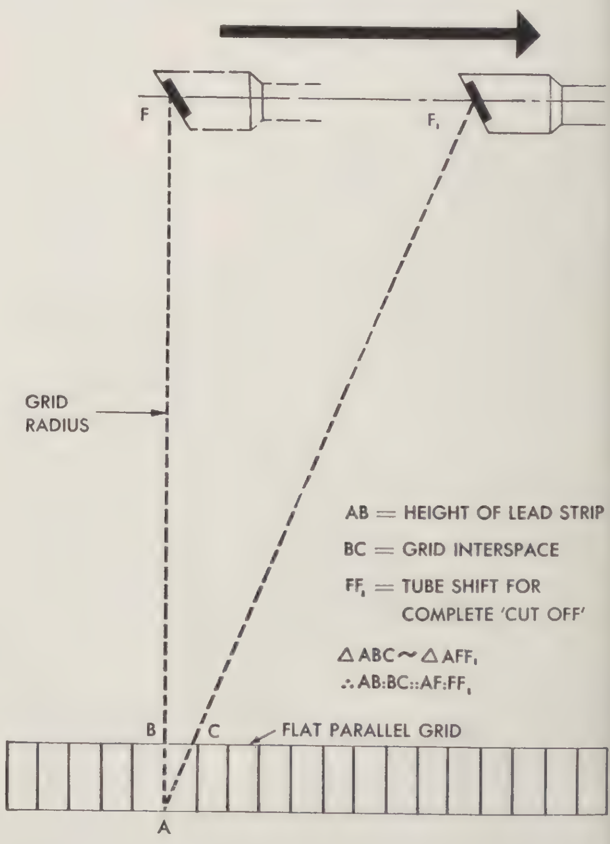


Figure 70. Relation between "cut-off" and grid ratio.

The grid ratio might be determined by positioning the X-ray tube off center to the extent of the geometric base as considered in relation to the similar triangles. (See fig. 70.) For example, if it is thought that the ratio is 5 to 1 and the radius is 30 inches, the geometric relationship would be: 5:1::30:x—indicating that a shift of the X-ray tube to the extent of 6 inches should result in a complete cut-off of radiation effect.

89. INTENSIFYING SCREENS. The intensification factor of intensifying screens (par. 123) may be determined by comparing the density of films made with intensifying screens as compared with the density obtained without intensifying screens. This may be accomplished by making simultaneous exposures upon the two films with all factors being constant except time. The exposure should be made at different kilovoltages ranging from 30 to 90. The films should be processed in fresh developer in accordance with time-temperature development. Densitometric readings are then obtained of each exposed area of the film and these values are plotted for each kilovoltage so that the comparisons may be made. The figure 71a illustrates the plotting of the intensifying screen densities as compared with the densities obtained without intensifying screens made at 70 kvp. At this kilovoltage and a film density of 1.0 the intensification factor is 27.36. A film density of 1.0 is the ideal value to make the foregoing comparison. The factor may be obtained in this manner for each kilovoltage. These values may be plotted and the average intensification factor of a particular type of intensifying screen obtained. (See fig. 71b.)

SECTION III. TROUBLE ANALYSES; MAINTENANCE AND REPAIR

(See also app. IV.)

90. GENERAL. The term, maintenance of X-ray equipment, should not be construed, solely, as meaning repairs to keep the equipment functioning. It should be thought of, primarily, as preventing failures in operation by routine checking, cleaning, and the elimination of improper handling. Before attempting to remedy X-ray equipment difficulties, the approach of the trouble must be systematic and

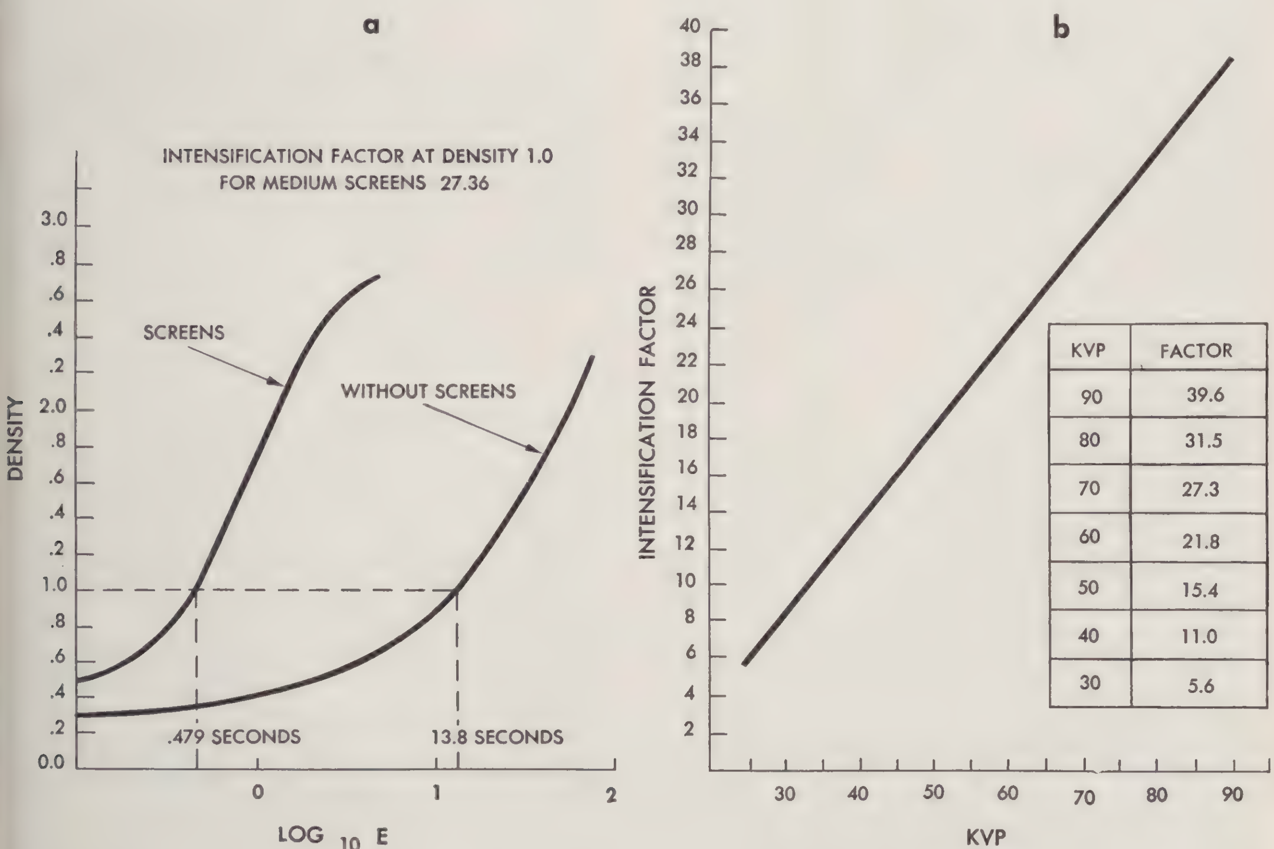


Figure 71(a). Example of determination of intensification factor at 70 kvp.
(b). Effect of kilovoltage on intensification factor—medium screens.

analytical. The wiring diagram should be studied and above all else, common sense must be utilized to the highest degree. Consider the trouble possibilities in relation to each circuit. In most instances the difficulty is of a minor nature. Hesitate before proceeding to dismantle intricate and expensive components. Practically all electrical troubles are caused by open, loose, or short connections.

91. X-RAY MACHINE UNITS—MANIFESTATIONS OF TROUBLE. When the main switch is closed and none of the circuits are energized it is obvious that the trouble is at a point common to all circuits. Therefore, the cause of trouble must be between the source of supply and the point of distribution within the unit. This trouble may be in the source of supply; connections at the source; failure of one or more fuses in the unit; main switch or the circuit breaker (which may be connected in the main line) being in the "off" position. It is desirable that a test set, consisting of two 110 volt lamps connected in series, be available for testing purposes. If the set is used across a 220 volt line each lamp will burn at normal brilliancy; if the voltage is 110 volts, each lamp will give light at less than half brilliancy but sufficient to indicate continuity of the circuit. If one tests the incoming line at the control stand one should be able to localize the trouble from there back to the energizing source, or from there through to the center of distribution within the unit. Fuses can be tested for continuity by a crossed terminal method. (See fig. 72.) Never throw away a fuse until absolutely sure that the fuse is open circuited. Furthermore, do not discard an open fuse of the cartridge type in the theater of operations where replacements are not readily obtainable. Use can be made of the good part of a fuse link as a protection device by reducing the cross section of the fuse wire or link to approximately the same thickness as that of the effective part of the normal fuse. When replacing fuses be sure that the current carrying capacity of the new fuse is *of the proper value.* A burnt out fuse implies the fact that there is an overload beyond it. This condition may be located by checking each individual circuit of the unit. The various circuits of X-ray units may be considered for trouble analyses in the following manner:

X-ray tube filament circuit (fig. 25).
Primary circuit of high tension transformer (fig. 26).
Timer circuit (fig. 27).
High tension circuit (figs. 31 through 33).
Valve tube filament circuits (fig. 33).

92. X-RAY TUBE FILAMENT CIRCUIT. This circuit includes that part from the primary connection at the line or autotransformer source through the filament regulator, filament current indicator; fila-

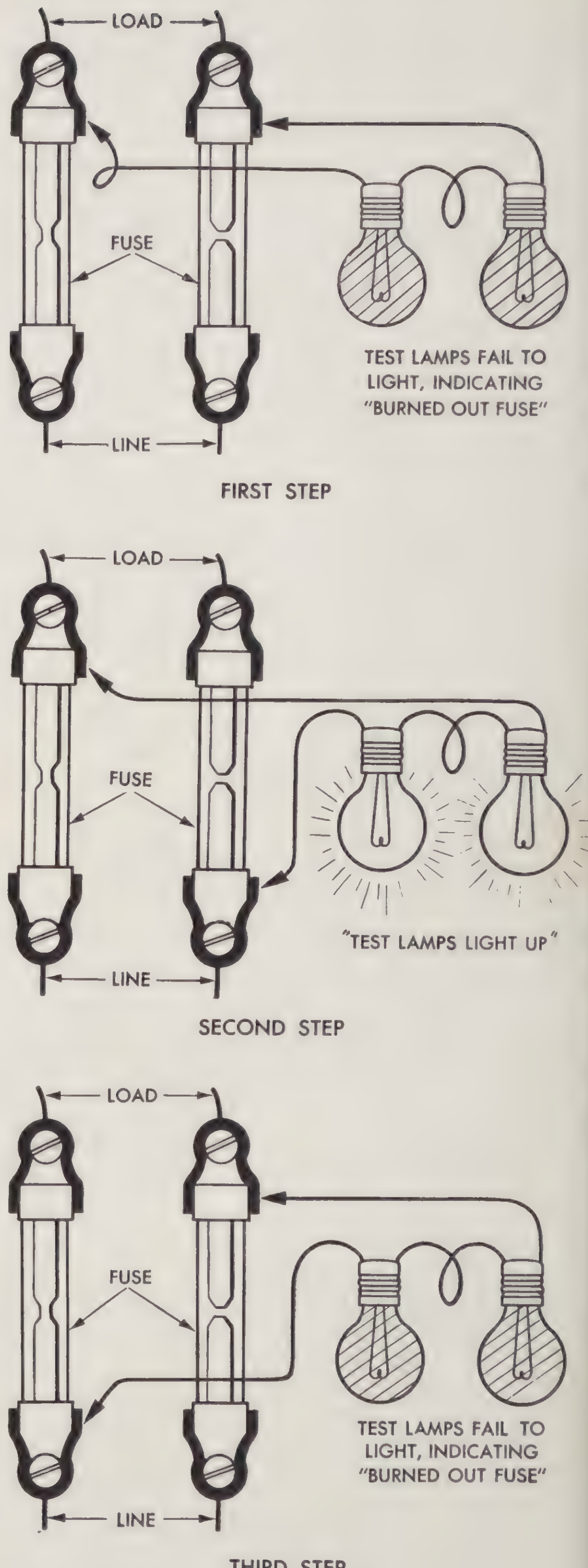


Figure 72. Continuity test for fuses.

ment transformer, secondary circuit of filament transformer to the filament within the X-ray tube. The first approach to trouble in the filament circuit is to test the primary leads as they enter the filament transformer. If there is no indication of voltage then the trouble lies from there back to the source. If there is an indication of voltage then the trouble is between that point and the filament of the tube. A voltage will be indicated by lighting of the test lamp. One must not assume that the primary or secondary of the filament transformer is open circuited unless one can determine definitely if this is so without opening the transformer housing. Since it is impractical to carry spare X-ray tubes or X-ray tube housings as a routine procedure, one should eliminate the tube or tube head as a source of trouble in order that a requisition may be forwarded immediately in the event a tube replacement is indicated. The voltage across the tube filament terminals is low in value—usually 10 to 15 volts. Since filament transformers will withstand a short-circuited condition for a short period of time, the filament leads may be connected with a piece of wire or a coin and if a spark occurs it is certain that the circuit is functioning normally to that point. However, it must be remembered that *these leads are at a high potential* with respect to ground *when the high tension transformer is energized.* Therefore, care must be exercised that the switch or switches in the primary of the high tension transformer are not closed. If there is arcing as explained above, it may be concluded that the trouble lies between the end of the cables and the filament of the X-ray tube. This does not indicate definitely that the filament is open circuited, for the trouble may be a poor connection at the junction of the cable and the tube head terminal. More than 50 percent of the trouble in X-ray equipment occurs in the filament circuit. This is due primarily to the fact that the filament circuit—primary and secondary—is operated at a relatively low voltage. Therefore, a slightly loose connection will produce sufficient resistance to provide a comparatively large voltage drop, thereby reducing the current through the filament of the X-ray tube. Since a slight reduction in the filament current will produce a marked decrease in the electronic emission, there will be a relatively large reduction in the tube current. It is obvious, then, that emphasis should be placed upon the security (mechanical and electrical) of all connections. If the trouble lies between the source of supply and the primary of the filament transformer the cause may be in the filament regulator or indicator. To test the regulator, place the test lamp leads across the primary binding posts of the filament transformer and change the position of the regulator over a wide range. If there is a change in the intensity of the light, it may be concluded that the regulator is functioning normally. If there is no energizing of the test lamp or if there is no change in the light intensity, then the regulator is the cause of the failure. If the current measuring device is an ammeter, it may be bypassed; that is, short circuited out of the filament circuit. If it is the cause of failure the filament of the X-ray tube will then be energized. If the filament indicator is a voltmeter (as in the U. S. Army Field X-ray Unit) one can obtain function of the unit without the use of the meter, even though the meter does not register. It should be understood therefore, that with some X-ray units, mechanical failure of the filament meter will not prevent the flow of current. The simplest method of determining such a condition is to place a fluoroscopic screen in front of the exit portal of the tube head. If the screen is activated then X-rays are being produced even though the filament current measuring device is not indicating.

93. PRIMARY CIRCUIT OF HIGH TENSION TRANSFORMER. If there is an indication that the filament circuit is functioning normally and there is no evidence that high voltage is across the X-ray tube, the trouble may be in the primary of the high tension circuit proper or in one of its auxiliary circuits. The prereading voltmeter is located in the primary circuit between the autotransformer controls and the primary of the high tension transformer. If there is no movement of the meter needle it may be that one or both autotransformer controls are placed upon an intermediate button which is not connected in the circuit. This can be determined by moving the controls, slowly, in either direction away from the "dead" button. If this meter functions and a different reading is obtained when the autotransformer controls are changed, it may be concluded that the autotransformer and the autotransformer controls are not the cause of trouble. If the prereading kilovolt meter is broken and the foregoing means of determination are not feasible, and if a "hum" can be heard from the autotransformer then it can be realized that the primary circuit of the autotransformer is energized. A simple means of testing the primary circuit of the high tension transformer is to place a lamp across the primary leads and operate the unit as usual. If the lamp lights when the timer contactor is energized the entire primary circuit and auxiliary circuits to the high tension transformer are in operating condition. If the lamp fails to light the trouble is in the primary or an auxiliary circuit.

94. TIMER CIRCUIT. The timer or contactor circuit should next be tested. In most units the normal operation of the contactor circuit is indicated by a noise as the electromagnetic contactor "makes" or "breaks." The absence of such noise indicates that the circuit is open at some point. A visual inspection of the wiring of the contactor circuit will very often

be sufficient to locate the trouble. If this procedure fails to locate the trouble then one should eliminate one section of the circuit at a time. For instance, pressing the timer button activates a clock mechanism. The timer button may short-circuit two leads or cause the clock mechanism to short-circuit the leads. If these two leads are short-circuited within the timer proper or at any place that one could eliminate the clock mechanism then if the contactor "makes," one can conclude that the trouble lies in the button or clock mechanism. In some forms of timers one energizes a magnetic coil, which in turn causes a clutch arrangement to function; if the clutch face is oil soaked there will be slipping of the clutch which will be manifested by irregular timing. Chattering will occur in the contactor case since the slipping clutch will permit "making" and "breaking" of the circuit at very short intervals of time. In case of a slipping clutch, the plates should be checked to make sure that they are free of oil and that the spring holding the plates is set with sufficient tension. When an electric circuit is opened or closed there is a tendency to produce heat at the point of contact. The contactor points should be kept clean and spaced correctly. They should be cleaned by the use of sandpaper if excessive sparking is present. Care should be taken to clean the surface of the points in a uniform manner, in order to prevent the formation of "high points." If sandpaper is not available, emery cloth can be used but one should be definite in "blowing out" all metallic particles since these particles are conductors and, if not removed, they may cause a short-circuit within the contactor. The spinning top test (par. 87) should be made whenever repairs have been made on any timer. The foregoing tests should be sufficient to locate the trouble in the primary or auxiliary circuit and the necessary repairs can then be made.

95. HIGH TENSION CIRCUIT. If the test at the primary leads or the transformer indicates that the trouble is from there through to the X-ray tube, it is possible that failure may be in one or more of the following: loose connections in the primary circuit within the transformer housing; loose connections in the filament circuit of a valve tube, if used; leakage of high voltage to ground, either through the oil within the transformer housing or across insulation of nonshockproof equipment and through insulated cables in a shockproof unit; break-down of the insulation within the tube head, and finally, insulation failure of the X-ray tube. Do not open a transformer housing except as a last resort; check all primary connections, first. In any loose connection carrying a relatively large current, there will be production of heat which will manifest itself in the formation of copper oxide which should be quite obvious. Leakage to ground across or through an insulator is a common cause of failure on nonshockproof equipment, especially in areas where there is a relatively high humidity or where insulators are not cleaned at regular intervals. Hence, it is definitely necessary that routine cleaning of all high tension conductors and insulators be accomplished. Discharge to ground within a transformer housing is usually due to failure of the oil insulation. Oil insulation failure may be due to: low oil level, moisture content in the oil, or contamination by dirt (especially, metallic deposits). If the oil level is low, additional oil must be added. If regular transformer oil is not available, pure medicinal oil can be added safely, preferably from an unopened bottle. The oil should be added slowly to prevent the formation of air bubbles and the transformer should be allowed to remain at rest for approximately 24 hours to permit the air bubbles to rise to the surface. It this is not practical, the unit might be energized at about 2 milliamperes and 30 kvp for 2 minutes; thereafter, repeated energizations should be made, raising the kvp in steps of 10, operating at each step for 2 minutes until the maximum kvp is reached. This produces slight increase in temperature within the transformer housing and causes the air to rise to the surface at a more rapid rate. If a unit is transported over a rough road and all the oil has to be replaced, either of the above procedures must be followed. If all the oil in a transformer housing is to be replaced, care should be exercised that the housing is cleaned of all foreign material.

96. VALVE TUBE FILAMENT CIRCUIT. Valve tube filament failure would be indicated by the filament not being lighted. A loose connection in the valve tube filament circuit will produce a reduced intensity of light in the filament. Valve tube replacements should be cleaned and dried before immersion in the oil and the current filament regulation should be set as prescribed by the manufacturer. This current value may be indicated on a chart accompanying the tube or stamped upon the base of the tube. The filament current of a valve tube can be adjusted by resetting a tap on a resistor (located within the control stand). These resistors are labeled and setting should be made for the maximum milliamperage that may be used. Proper setting of the valve tube filament current (allowing for the maximum milliamperage) is extremely important. A low setting will cause excessive heating of the plate of the valve and thereby reduce the useful life of the tube.

97. TUBE FAILURES. Failure of X-ray tubes are confined to three distinct causes: gassiness, destruction of filament, and tube puncture. Gassiness of the X-ray tube is usually due to originally occluded gases seeping out from within the metallic parts of the tube to within the envelope. It may be caused by residual gases due to failure of the manufacturer to

adequately "de-gas" (season) the tube or to volatilization of metals due to overloading the tube during operation; overloading such as will cause pitting, glazing, fracturing, or actual melting of the target. The pressure within a tube may be so low that the tube can be operated at a reduced voltage and a limited amount of roentgenography accomplished. Voltage applied across an X-ray tube will cause ionization of gases contained therein. Normally, the degree of ionization is insignificant. However, as the pressure of the gas within the tube increases, the total ionization increases and an arc between the two electrodes may result. A slightly "gassy" tube will manifest itself by a fluctuating milliampere reading which may start as an intermittent discharge across the tube and very quickly provide a sustained arc unless the machine is shut off immediately. If a discharge through a tube is maintained for even a short interval of time the filament will usually be destroyed. It is more difficult to diagnose a "gassy" tube in a modern shockproof unit than in the old open tube type of units, since one cannot observe the effect of the ionization of the gas within the tube in the former. Hence, one must make the diagnosis on the basis of operation of the milliammeter. When a sparkover occurs within the tube the milliammeter will usually read off scale, that is, to the extreme right, until the arc is interrupted (perhaps by the circuit breaker). Another method to determine gassiness is to apply approximately 50 kvp across the tube with the filament not energized. If the tube is not gassy the milliammeter will not indicate. The failure of X-ray tube filaments may be attributed to the fact that it has reached its maximum life of usefulness. Just as a filament in an ordinary light bulb has a normal operating period, so too has the filament of an X-ray tube. The life expectancy of the filament is dependent upon the care and operation of the X-ray tube. The filament of the X-ray tube should not be operated in excess of the values recommended by the manufacturer. Tube punctures are caused by short circuiting of the high voltage within the tube to ground. In air-cooled tubes inclosed within a ray-proof housing puncture may occur where the impressed voltage exceeds the dielectric strength of the insulation between the insert tube and the housing. It will occur at the point of greatest electrical strain and mechanical weakness of the glass. Loss of oil in an oil immersed tube housing will eventually result in a tube puncture. It is possible that break-down of the insulation within the tube head can be corrected. If air is the insulating medium, then several small points or *one large point of carbonization* can be observed usually on the insulator terminal. It indicates that the distance between the high tension lead and ground has been reduced. Removal of the carbon will usually permit normal operation of the unit. The heavy portion of the carbon deposit may be removed by scraping and the remainder with carbon tetrachloride. If the tube is oil immersed it will require a complete replacement of the oil.

98. CABLE FAILURE. Modern shockproof cables withstand voltage strains for which they are designed provided mechanical abuse does not destroy their dielectric strength. Cables should not be bent too sharply, nor should any great mechanical strain be placed upon them. If break-down occurs at the maximum voltage it may be possible to use it at a reduced kvp, if the carbon formed at the time of the initial break-down is removed. Loose connections at cable terminals are a frequent source of trouble. They can be avoided by making the terminal connections mechanically and electrically secure. Castor oil or petrolatum may be placed into the receptacles to maintain insulation. These substances tend to prevent the moisture from being deposited upon the cable insulation proper and to act also as a lubricant. Periodic cleaning of insulators is one of the most important procedures for cable maintenance.

99. GENERATOR, GASOLINE ELECTRICAL, ITEM NO. 96060. The gasoline electric generator has a capacity of 2,500 watts. This unit may be the sole source of electrical energy in a theater of operations. It should therefore be handled with care. The proper grade of oil must be used in the crank case and should be changed after 100 hours of operation. The correct grade of oil depends upon the temperature of the location at which the unit is used. Oil grades are listed in the manual which is with each unit. Oil must be kept to the proper level. The filters in the fuel supply line must be cleaned at intervals to eliminate the possibility of dirt eventually reaching the carburetor and thereby clogging the fuel supply or permitting excess wear on the needle point and destroying the fine degree of adjustment necessary for proper performance. Checking of the spark plugs and magneto breaker must be performed routinely. The gap of each spark plug should be as prescribed by the manufacturer. The generator commutator and slip rings must be kept free of dirt and rough surfaces. Care must be exercised that the brushes be properly seated so that they have uniform surface wear and thereby give prolonged operation. The air inlet to the carburetor contains a filter to prevent dirt from entering the carburetor proper. This filter must be cleaned about every 200 hours of operation, and more frequently if located in an area in which the air has a high dirt content. Inability to start the internal combustion engine may be caused by a lean gasoline mixture. This can be corrected by "choking" the carburetor to reduce the relative quantity of air. The presence of water in the gasoline will result in poor operation. The best procedure in this instance is to drain off the gasoline and refill the tank with clean fuel. A common cause of failure is due to

closure of the air vent on top of the gasoline tank cap. This vent must be opened so that the gasoline is under atmospheric pressure at all times of operation. If the contact points in the magneto breaker are "fouled" or not adjusted properly, definite "making" or "breaking" of the circuit will not occur and a voltage of sufficient value to jump the gap of the spark plug will not be produced and no ignition will take place. Improper gap spacing in one or both of the spark plugs will also prevent the production of a spark and again no ignition will occur. One should be on guard as to the possibility of a break or failure in the insulation of the wiring of the ignition system. It must be remembered that the gasoline electric generator should not be started with a load connected to the generator, nor should it be stopped under load. It is important to emphasize that the gasoline generator has been specially designed as a source of power for the Field X-ray Units (96085–96215). It is not feasible to use this generator as a source of power for other electrical devices and equipment because the generator output voltage is approximately 128. This voltage is too high to apply to most electrical equipment. If other apparatus such as electrical sterilizers, surgical lamps, ordinary light bulbs, etc., designed for 115 volts, were to be connected into a circuit energized by this generator, the voltage would be in excess of that intended with the result that excessive current would flow and reduce their useful life.

100. FIELD PROCESSING UNIT. a. This unit has been designed to operate from a community water supply or as a self-contained unit inasmuch as it does not need a continuous inflow of water to satisfactorily accomplish processing of films. This latter feature is provided by means of a circulating water pump. It is only necessary to fill the tank section with water which will be cooled and circulated within the unit.

b. This item is made up of two components; that is, a base section which houses the cooling, heating, and circulating mechanism and a master tank which will accommodate the developing containers, hypo tank and also provide washing space for the films. (See par. 65.)

c. The processing unit has been designed to maintain an average water temperature of 65° F., in the master tank under average conditions. The instructions accompanying the unit should be studied in every detail before assembling the unit. Emphasis should be placed upon location of the unit that it shall not be required to do unnecessary work; for instance, do not locate in a damp poorly ventilated position. Furthermore, do not expose the unit to freezing temperatures after it is shut down unless all water has been drained from the system.

d. When the unit is to be connected to a community water supply it is necessary to consider the water pressure and temperature in order that the unit will function most satisfactorily and consistently. The proper orifice (supplied with the equipment) should be inserted into the incoming water supply and the pointer on the calibrated valve set to the community water temperature in order for the temperature control mechanism to maintain a uniform temperature. This point on the incoming water circuit is a source of trouble inasmuch as some particles of sediment cannot bypass the orifice and thereby clog the water line.

e. The unit is designed to operate on 115 volt a-c single-phase; 50–60 cycle and will draw a maximum load of 14 amperes. The unit should therefore be connected to a power supply of these specifications and if there are any deviations from the above, one should utilize a suitable gasoline electric generator (Item No. 99600). It is important that the processing unit be thoroughly grounded before connecting to the source of power. Make the ground connection to a cold water pipe, if available; if not, drive a ¾-inch pipe or metal rod into moist earth to a distance of at least 3 feet. The point of contact between the ground wire and the rod or pipe should be electrically secure.

f. Lubrication. It is important that the unit be placed on a reasonably level surface so that all parts of the compressor receive adequate splash lubrication. The oil level indicator of the compressor should show oil at least one quarter of the height on the bull's-eye gauge. Do not add oil other than the special type provided for the unit. Medium grade grease is used for lubricating the water pump and care should be exercised to prevent over-lubrication of the pump, thereby forcing grease into the unit and contaminating the circulating water. The water pump motor should be oiled with a few drops of SAE-20 engine oil and care taken, again, that the motor is not over lubricated. The fan motor of the refrigerant condenser *must not* be oiled since the lubricant is sealed in the unit so as not to contaminate it with oil or grease.

g. The following precautions should permit more efficient operation and longer useful life of the unit:

(1) Check the power supply line.

(2) Ground the equipment before operating.

(3) Reduce vibration by anchoring the unit, especially in transportation. (Do not forget to release anchor under compressor before operating the unit.)

(4) Keep valve caps of refrigerating system secured in position to prevent loss of refrigerant.

(5) Level the unit as much as feasible to eliminate excessive wear on rotating parts.

(6) Fill the tank with water as near 65° F., as possible, alleviating the unit from unnecessary work.

(7) Locate the unit so that air can circulate entirely around it.

(8) Remove dust from the condenser radiator at frequent intervals; this will increase the efficiency of operation.

(9) Do not operate the unit without water, the heating element will burn out if this is attempted.

(10) Never attempt to raise or shift the entire unit by means of the handles on the main tank.

(11) Clean all screen mesh strainers frequently so that no foreign material can enter the circulating system. These mesh strainers must be in position at all times while the unit is being operated. Keeping the mesh strainers clean helps maintain better temperature control of water in tank section.

h. Possible troubles in the processing unit with probable causes:

(1) *Water does not cool.* (*a*) No power; cooler or line switches open.
(*b*) No water circulation.
(*c*) Mixing chamber air bound.
(*d*) Compressor motor not operating.
(*e*) Refrigerating unit not cooling.
(*f*) Water temperature control not functioning. (See par. j.)

(2) *Water does not heat.* (*a*) No power; heater or line switches open.
(*b*) No water circulation.
(*c*) Mixing chamber air bound.
(*d*) Heater element not operating. (See par. j.)

(3) *No power.* (*a*) Main line switch open.
(*b*) Fuse open circuited.
(*c*) Broken wire or open connection in supply line.

(4) *No water circulation.* (*a*) Water level below top screened outlet pipe; water must be added.
(*b*) Water valves not adjusted properly; check all valves.
(*c*) Water pump not operating; check wiring back to source of power; check pump packing nut for "tightness"; check pump impeller for possible failure.
(*d*) Water pump air bound; release air through small orifice through grease cups while pump is operating. Reset grease cup cap with care to prevent forcing grease into water circulating system.

(5) *Mixing chamber air bound.* Unit drawing in air through screened inlet pipe because of improper water level; increase water level and "bleed" unit through air vent at end of mixing chamber.

(6) *Sealed compressor motor not operating.* (*a*) No power; check cooler or line switches.
(*b*) Water temperature relay contacts fail to open or not contacting properly; clean and readjust contacts.
(*c*) Refrigerant pressure control contacts pitted or not closing properly; clean and readjust contacts.
(*d*) Starting capacitor burned out; replace with spare.

(7) Liquid line, suction line or receiver shut-off valves, not opened; check all valves; do not operate unit with any of these valves closed.

(8) *Refrigerant unit not cooling.* (*a*) Liquid line, suction line or receiver valves only partially opened.
(*b*) Loss of refrigerant due to broken line or leak.

(9) *Water temperature control not functioning.* (*a*) Air in mixing chamber; open air vent.
(*b*) Thermostatic element defective; check the setting by use of thermometer immersed in main tank. (See par. j.)
(*c*) Moving contact jammed.

(10) *Heating element not operating.* (*a*) No power; heater or line switches open.
(*b*) Water temperature control contacts fail to close or are making poor contact.
(*c*) Relay not contacting properly on normally open contacts.
(*d*) Burned out relay coil.
(*e*) Loose connection on heater terminals. (See par. j.)
(*f*) Complete failure of heater element.

i. In all cases of failure of the refrigerating system where repairs are necessary it is absolutely essential that reference be made to the manual as supplied by the manufacturer.

j. Temperature control. Due to vibrations in transport and while the unit is in operation it is possible that the unit will not maintain a temperature of 65° F., even though there is no apparent failure of the cooling and heating mechanism. This may occur when the thermostatic temperature control contact assumes a new position due to these vibrations. By making adjustments on the movable contact arm and allowing the cooling compressor to run until the water temperature in the master tank reaches 65° F., it can be readjusted so as to maintain a uniform temperature. When the temperature reaches 65° F., the movable contact arm should be placed close but barely touching the contact on the thermostatic element. The movable arm should then be secured by locking its position on the scale which is on the bottom edge of temperature control box. After a few trials, the adjustment can be made where the cooling compressor will be energized when the water in the mixing chamber reaches 68°. It will continue to cool until the water in the mixing chamber reaches 62° F., at which time the heating circuit will be closed until the water again reaches a temperature of 68° F. It should not be necessary to have both the heater circuit and the cooling circuit operative. In very warm weather the switch to the heater circuit should be opened; while in cold weather, that to the cooler circuit should be opened. The heating circuit is set for 300 watts when the unit is received from the Medical Supply Depot. However, in cold climates it may be desirable to have greater and faster heating of the water. This

can be accomplished by rearranging the heating elements in parallel to the power supply. Connecting both elements in series will provide 300 watts; connecting only one element into the circuit, 600 watts; and by connecting both elements in parallel, 1,200 watts can be obtained. Instructions for making these connections are given in the service manual accompanying the equipment.

101. FIELD DRYING UNIT, ITEM NO. 96055. a. Electrically, the Army Field Dryer consists solely of a blower and a heating element. The fan operates on 115 volts a-c, 50–60 cycle and draws a starting current of 3.5 amperes, while the running load is 1.5 amperes. The heating element load is 18.4 amperes; therefore, the total load when both blower and heater are energized is approximately 20 amperes (that is, practically the total capacity of Item No. 96060). The unit is so arranged that the heater cannot be operated separately. This arrangement is provided to prevent rapid failure of the heating element. The fan can be operated independently of the heater and the unit should be so used when the room temperature is above 75°. There is no practical value in energizing the heater unless the circulating air must be warm in order to expedite the drying of the films.

b. The fan should function indefinitely if kept clean and if the bearings are oiled regularly. If the heating element is kept clear of moisture and dirt it should give long service. Failure of either one of these sections should be obvious. The probable causes include: failure of the switch or connections thereto; a possible broken wire from the switch to the fan or the heater; an open circuit in the element proper; or a poor connection in the blower itself. Visual inspection of these parts should be sufficient to locate the point of failure and the necessary repairs should be self evident.

CHAPTER 5

ELECTRICAL AND RADIATION PROTECTION

102. GENERAL. In dealing with X-ray equipment, two types of hazards must be respected: electrical dangers and X-radiation dangers. These concern the roentgenologist, technicians, and patients.

103. ELECTRICAL HAZARDS. a. The use of shockproof equipment is now so prevalent that electrical dangers have been almost eliminated. However, the safety provided by this type equipment is of itself a danger because it is likely to relieve too completely the mind of the operator. After handling trustworthy shockproof equipment, there is considerable likelihood that novice X-ray technicians may fail to recognize the electrical hazards which exist as far as the operation of non-shockproof equipment is concerned. Moreover, everyone should realize that regardless of self-contained tube heads (that is, when the X-ray tube is immersed in oil and contained in the same tank which accommodates the high tension transformer), or with the use of shockproof cables, one is still handling currents of exceptionally high voltage which under certain conditions might overcome the protective provisions. Therefore, even with modern shockproof equipment, the possibilities of electrical hazards should be respected.

b. Physiological effects. Death may result from any one of four physiological effects:

(1) The ventricles of the heart may be thrown into fibrillation from which, in the human, they seldom or never recover.

(2) Tetanic convulsion of the respiratory apparatus may occur with resultant fixation of the muscles of the thorax and the diaphragm in the phase of deep inspiration.

(3) The brain centers concerned with constriction of blood vessels may be so stimulated as suddenly to produce extremely high blood pressure with resultant hemorrhages.

(4) The resistance on the part of the tissues to the flow of the electrical current may be so great as to produce extreme accumulations of heat with the result of actual charring.

c. Voltage versus current factors. Contrary to general belief, voltage is not the factor directly responsible for any of these effects. It is amperage that causes fatalities, and of greatest importance is the amount of current which is effective upon the heart. It has been estimated that for the frequencies of current utilized with most roentgenographic equipment (60-cycle), the human heart will tolerate no more than 6 to 15 milliamperes. The heart is involved to the greatest extent when the electrical contacts include one upper extremity and the opposite lower extremity, for with such a contact, approximately 10 percent of the total current involves the heart. Interpreted as total current flowing through the body, by such a route, a minimal lethal value would amount to between 60 and 150 milliamperes. Some individuals have idiosyncrasies (either because of defects in their heart or because of an overly excitable nervous mechanism), and they cannot tolerate even the lower of these values. It is estimated that approximately 90 percent of injuries incident to electrical shock are those concerned with the heart—hence, the importance of these considerations. With high voltage and very low amperage (that is, milliamperage), there is a tendency for an individual to be thrown for a distance. With lesser voltage and sufficient current to stimulate muscle contraction, a complete gripping contact is likely. A certain amount of voltage is required to overcome the resistance of the skin and superficial tissues. This value varies, depending upon the dryness of the skin, the thickness of it, and the amount of fat contained in the subcutaneous tissues. With very moist skin and a thin individual, it has been estimated that only 65 volts are required to overcome all body resistance.

d. First aid. Regardless of the unfavorable possibilities, every effort should be made to restore a victim from electrical shock. However, one should never directly grasp the individual, because by so doing the result will most likely be suicide with the accomplishment of no aid whatsoever to the first victim. Instead of plunging to one's own death, the first objective should be to break the electrical circuit by opening a switch. Perhaps the victim might be disentangled by throwing over him, a sheet or rope or some other nonconductor and then forcibly removing him from the contacts. Thereafter, he should be treated as a victim of shock. He should be placed in the lying position, prone, with his face turned to one side and chin resting on the back of one of his hands—to provide for freedom of breathing. His collar and other clothing should be loosened and then the Schaefer method of resuscita-

tion (as used for the semidrowned) should be instituted. (See fig. 73.) The chest manipulations should be continued at a rate of about 12 to 15 times per minute, without cessation, for as long as 2 to 4 hours—awaiting the arrival of a doctor.

e. Prophylactic measures. This treatment is effective in only a small percentage of cases. However, one should not despair in attempting to revive a victim of this sort. The poor results of treatment should emphasize the importance of avoiding the possibilities of electrical shock. All parts of roentgen ray equipment which may be touched by a patient, or by the roentgenologist, or the technician, during the course of an examination, should be well "grounded." (See par. 30.) This includes the roentgenographic table, tube support, control panel, and the transformer housing. Even though the control panel of the roentgen-ray machine be grounded, control switches should not be handled with wet hands. In the case of nonshockproof equipment, all high voltage wires and instruments should be mounted in inaccessible places, where they can be seen, but not touched. If low positions must be used, then metal grounded grills should surround them. Signs, attracting everybody's attention to the high voltage should be posted wherever danger exists. Loose, dangling wires are always dangerous and should not be tolerated. Machines, containing condensers in the high voltage generating circuits, are especially dangerous if the condensers are exposed. Such condensers retain their high voltage charge for many hours, or even days, although the machine is turned "off." Contact with the condensers may discharge them through the body.

104. ROENTGEN RAY HAZARDS. a. General. It is a widely known fact that a single large exposure to X-radiation or repeated small exposures to it may produce tissue injuries such as dermatitis, endothelial changes with the possibility of ulcer formations or neoplastic developments in the skin, destruction of blood cells, inhibition of the hematopoetic system (with the production of an anemia or leucopenia), neoplastic changes of it (with the production of a leukemia), inhibition of glandular activities (in particular, of the reproductive glands), and actual deformations of a growing fetus. Very severe injuries to the superficial tissues and numerous deaths have occurred because of X-radiation exposures, particularly during the first two or three decades following the discovery of the X-ray. The dangers were then not realized; maleffects were due

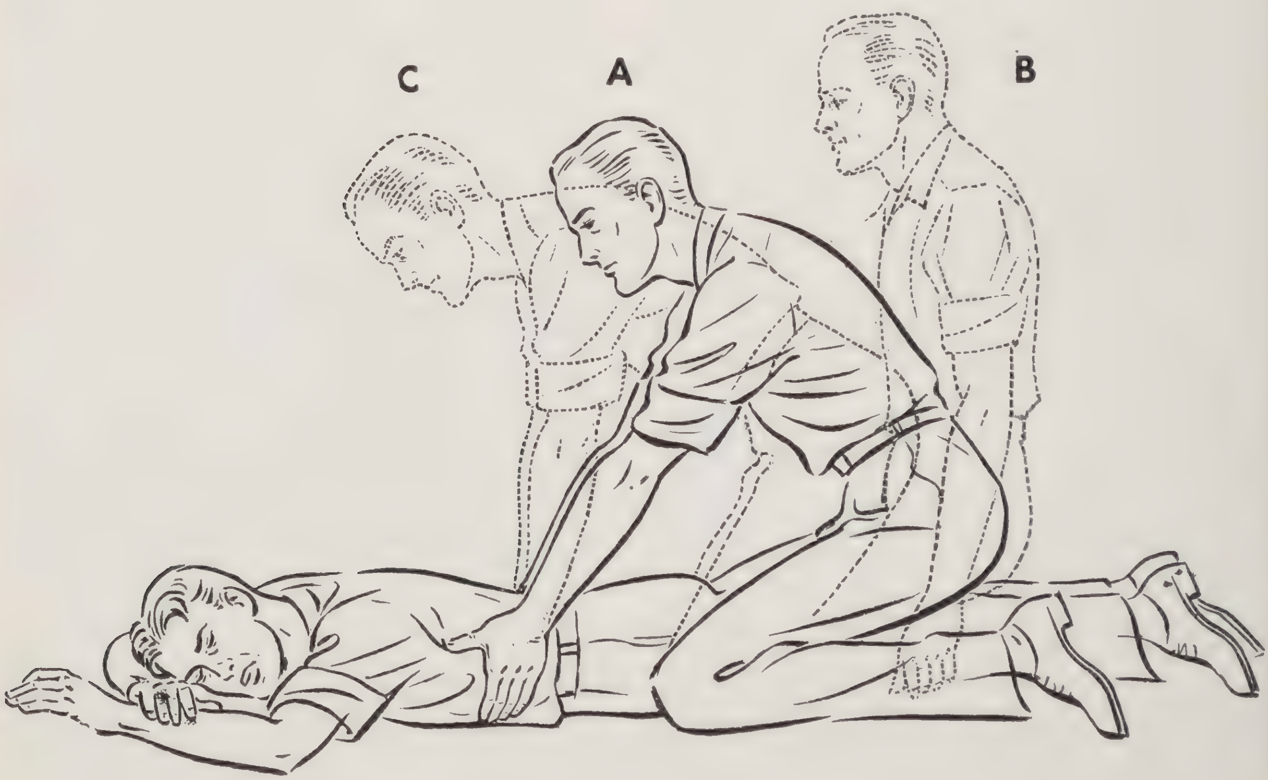


Figure 73. Schaefer method for resuscitation.

to ignorance as to the biological sequelae. The martyrs of those days were responsible for the incorporation of numerous protection features into the design and construction of equipment. Most of these provisions have been concerned with protection against the X-rays emitted from the X-ray tube itself—the primary X-rays. Ordinarily, too little consideration has been given to secondary radiation—the X-radiation which is emitted from table parts, the patient, and equipment in the exposure room.

b. Tolerance dosage. Considering all sources and types of X-radiation, a comprehensive evaluation of the threshold limits for the human (that is, the maximum daily tolerance which may be incurred without the development of maleffects) is not available today. One might consider limits of exposure which could be tolerated by the superficial tissues of a portion of the body, the limits of tolerance to whole body radiation wherein not only the superficial tissues but also the blood-forming organs and blood cells become affected, or the maximum dosage tolerated by the reproductive glands. A variety of investigations and experimental studies have been conducted by such authorities in X-radiation physics as Kaye, Taylor, Failla, Quimby, Henshaw, Packard, Scheele, and Cowie, and committee members have been selected by leading radiological societies to study this problem in the United States and in Europe. At intervals since 1921, recommendations have been submitted by them. There has been some variation as to their interpretation and definition of the maximum daily tolerance dosage. However, it has always been considered to be of very small quantity and in more recent years there has been a definite tendency toward downward revision of this quantity. Depending upon the prospective, whether dealing with protection for one or another tissue or for all tissues of the body, the maximum daily tolerance dosage has been considered to be one or a few r–, 0.2 r–, 0.1 r–, or even as little as 0.02 r– per day.

c. Primary versus secondary X-radiation. Short wavelength X-radiation is to be most seriously considered as far as the deeper tissues are concerned. The superficial tissues bear the brunt of the longer wavelength X-rays. Therefore, within the realms of roentgenoscopy and conventional roentgenography, daily small exposures or any prolonged single exposure to X-rays of the primary beam must be avoided. Not infrequently, too much reliance is bestowed on the manufacturer and too much trust is given to the construction features of equipment. It is possible to eliminate exposures of the examiner to the primary beam but it is not possible to eliminate entirely exposures by the secondary rays.

d. Exposures during roentgenoscopy. The Army roentgenologist is responsible not only for providing protection to himself but he is also responsible for enforcing the maximum protection to the patient, his roentgenographic technicians, and other assistants. No doubt, the greatest amount of punishment by X-radiation is received in the roentgenoscopic room. There, during routine procedures, X-rays are being emitted from the table and from the patient and to a lesser extent from practically all objects in the room. Too often the radiologist considers himself too rushed to bother with the ordinary precautions of putting on a lead apron or using a pair of lead-impregnated gloves. Too frequently his technician is allowed to stand close to the patient and the table without any protection whatsoever. Occasionally instructions should be given that the technician never subject his hands or portions of his body to very close proximity of the patient or even to the primary beam for such purposes as holding an enema tubing, syringe, or other instruments. There is seldom any substantial reason for having the technician thus exposed. When necessary, ample protection with lead gloves and a lead apron should be provided.

e. Surgery with roentgenoscopic visualization. In some institutions, fractures are still being reduced under roentgenoscopic observation. Foreign bodies are being removed in the same manner. Such practices can only contribute to the large numbers of medical martyrs in this field. There was excuse for the many catastrophes of this sort in the early days of radiology, but there should be no excuse for repetitions of the mistakes made in those days, now that the treachery of X-radiation is understood.

f. Exposures incurred during photoroentgenography. Careless practices are likely to appear at induction examining centers. Personnel are faced with a new problem—the handling of chest examinations of large numbers, requiring as many as 400 to 800 exposures within an 8-hour day. Mobile lead shields are provided and their proper use must be observed. The fact is recognized that considerable secondary radiation may be scattered from the walls of the room and that in certain positions the lead shields provide only false security. Moreover, personnel must be alert to the possibilities of careless exposures particularly by the technician who is charged with the positioning of the candidate and also the technician whose responsibility it is to exchange the films. (See fig. 74.)

g. Exposures during conventional roentgenography. Lesser degrees of exposure are ordinarily encountered during conventional roentgenography. Occasionally, though, the technician carelessly operates a timer or X-ray switch at a distance which is too close to the patient and the X-ray tube. These practices must be avoided, and every effort should be made to utilize the full length of a timer cord or spacing of the control from the X-ray tube in order to allow the factor of distance to serve as one of the measures for protection.

h. Protection features of field X-ray equipment. A number of features have been incorporated in designing field X-ray equipment to provide for protection. Some of these features are as follows:

(1) For roentgenoscopy, there is a fixed focal-fluoroscopic screen distance (66 centimeters). This feature in the table unit (Item No. 96145) serves to obviate poor alignments of the primary beam or changes in the coverage of it by the fluoroscopic screen as might apply in case the fluoroscopic screen were allowed to move independently in relation to the X-ray tube. Many have advocated the use of a bonnet type of fluoroscope which might be carried on the head of the operator, thereby providing for conducting these activities in a lighted room. This plan and others similar to it were rejected for the very reason that they would incur too great a hazard of X-ray exposure.

(2) The coverage of the fluoroscopic screen is 12- by 16-inch, thereby providing not only for a large roentgenoscopic field but also for the maximum practical protection with respect to secondary radiation adjacent to the field of study. Many have recommended that in order to reduce the weight to a minimum and to facilitate the exchange of patients, the dimensions of the fluoroscopic screen would be 10- by 10-inch, as used in the World War. It was believed that the attributes of providing for protection against X-radiation outweighed the attributes of the smaller sized screen.

(3) For foreign body localization, marking of the skin surface is provided by a marker which can be manipulated *beneath* the fluoroscopic screen but without exposing the hands of the operator to the primary beam. This is made possible because, with the method of localization which is used, the distance between the roentgenoscopic image and the skin surface is subtracted and it is not necessary to position the fluoroscopic screen directly upon the skin surface. If it were necessary to position the fluoroscopic screen directly upon the skin surface, a perforation for admitting a skin marker would be required, as was the case with the equipment used in the World War.

(4) Stops are provided to limit the opening of the roentgenoscopic shutters and thereby limit the maximum spread of the primary beam to the extent that at the level of the fluoroscopic screen its area is confined to within 1 inch of the inside borders of the screen mounting. Thus, even with the most careless operation of the shutter controls, it is not possible to deliver a primary beam of such wide coverage as to permit escape of primary X-rays beyond the limits of the protection provided by the fluoroscopic screen and its lead-protected glass (protection equivalence of no less than 1.5 millimeters lead).

(5) The fluoroscopic screen and the X-ray tube are mounted on a C-shaped support which is adjustable in the vertical plane, thereby providing for varying the focal skin distance and utilizing the greatest focal skin distance possible for localizations—and the least part screen distance. This feature serves for minimizing X-radiation exposure upon the patient and reducing thereby secondary radiation from the tissues, while providing for the greatest degree of sharpness of detail for the roentgenoscopic image.

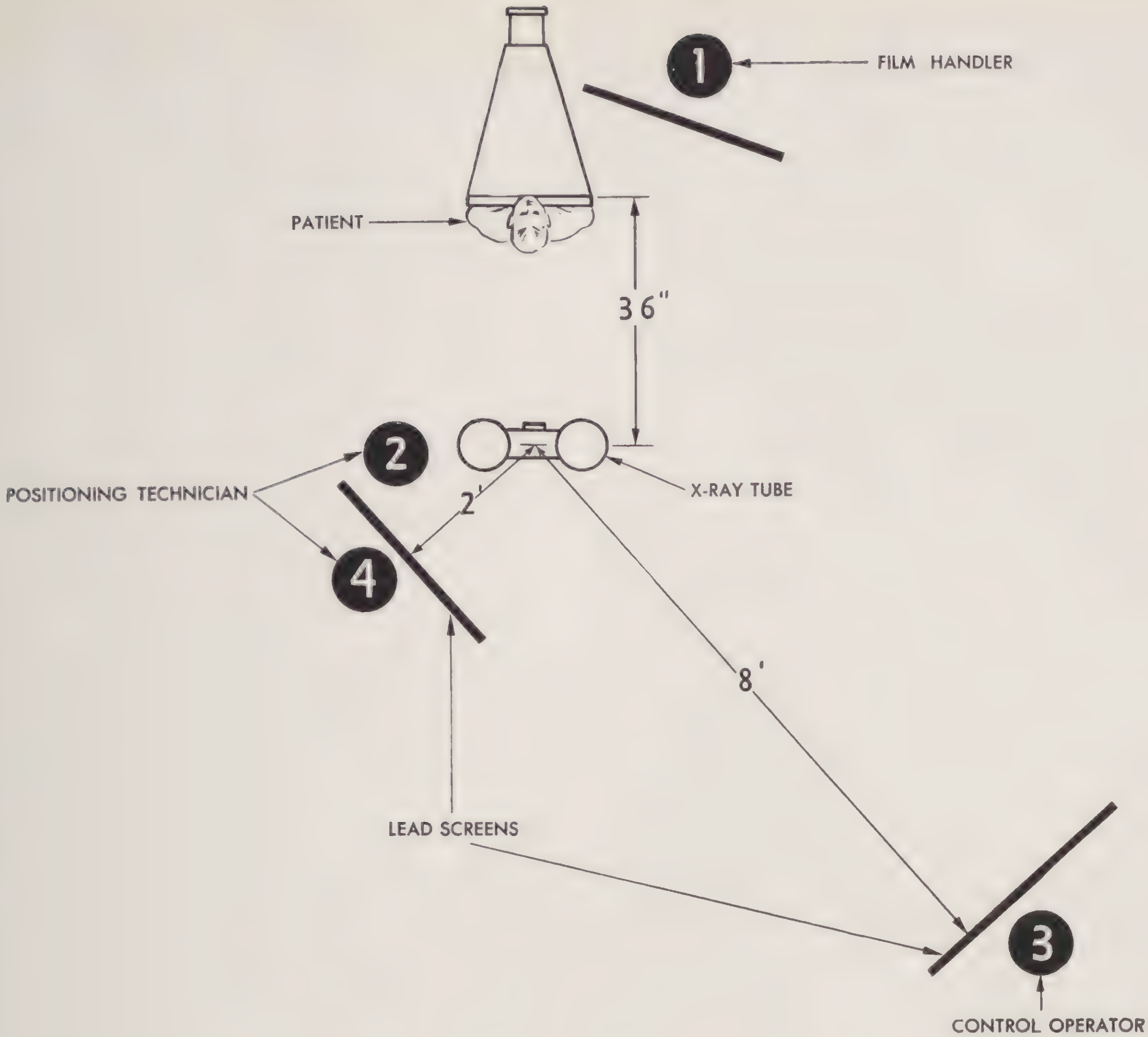
(6) The X-ray tube housing is impregnated with opaque material to such an extent that except for the portal intended for the primary beam, protection of the equivalence of 1.5 millimeters of lead is provided. This degree of protection should be adequate to filter X-rays of wavelength as short as those produced with the kilovoltage of 100—the maximum kilovoltage provided with the unit.

(7) Through the portal provided for the primary beam, the combined filtration is equivalent to that of 0.5 millimeter aluminum. This filtration consists of the wall of the insert tube (1 millimeter of pyrex glass), a thin layer of oil (1.5 millimeters), a 1.5 millimeter transparent bakelite wall, plus an added fixed filter of 0.25 millimeter aluminum.

(8) For roentgenoscopy, in addition to the filtration just described, there is a second fixed filter of 0.5 millimeter aluminum. This filter is fixed into the housing of the roentgenoscopic shutters. Thus, the total filtration during roentgenoscopy is consistent with the stipulations contained in paragraph 2.03 of handbook HB-20 as compiled by the advisory committee on X-ray protection and published by the National Bureau of Standards.

(9) The shutter controls are contained in the vertical portion of the C-shaped supporting member, referred to above, thereby providing for distance between them and the primary beam and the sources of secondary radiation. This feature serves to minimize the exposure incurred by the examiner's forearm and moreover it lessens the tendency for him to lean closely against the fluoroscopic screen whereby he would receive more extensive exposures to other portions of his body.

(10) The method of foreign body localization is such that only three short exposures for alignments are required. The localization procedure can easily be accomplished within 30 to 45 seconds whereby even with the very shortest focal skin distance (10 inches) a reasonable estimate of exposure incurred by the skin of the patient would be approximately 15 r–. The reading of the depth scale and the calibration scale can be made only while the X-ray exposure is interrupted, this feature being in contrast to so many methods which provide for reading of measurements with the assistance of the fluorescence from the fluoroscopic screen. (The light intensity of the pilot lights should be kept at a minimum and they should emit dim yellow or faint red light



10 PATIENT RUNS STEREOSCOPIC EXPOSURES

80-90 KVP

NO GRID — 20 EXPOSURES — 400 MAS		GRID — 20 EXPOSURES — 800 MAS	
1	.0045 r	1	.010 r
2	.025 r	2	.050 r
3	.001 r	3	.001 r
4	.001 r	4	.001 r

Figure 74. X-radiation exposures incurred by technicians during roentgenography.

in order to preserve the visual acuity of the operator to the utmost.)

(11) A variable resistance is incorporated into the foot switch circuit to limit the maximum milliamperage load. (See par. 83.) It is realized that well qualified roentgenologists will properly prepare their eyes by wearing dark goggles or by remaining in darkness for at least 5 to 10 minutes before starting roentgenoscopy. They will thereby develop an acuity of vision not requiring excessive kilovoltages or high milliamperages and they will accomplish roentgenoscopy with kilovoltages of 65 to 80 and milliamperages of 2 to 4 (that is, extremities with 65 kvp and 2 to 3 ma; for the chest, 70 kvp and 2 to 3 ma; that of the abdomen 80 kvp and 3 to 4 ma).

(12) The fastest type of fluoroscopic screen is provided, thereby obviating the need for relatively great X-radiation exposures.

(13) The table top is a standard United States Army litter. It is constructed of materials of low atomic densities—canvas and aluminum—rather than having a wide coverage of plywood or bakelite and metal framework. The secondary X-radiation emitted from the litter type of table top is considerably less than that emitted from conventional table tops and thus this source of secondary radiation is reduced and the radiologist is spared.

(14) A lead apron and a pair of lead-impregnated gloves are constituents in the chest which accommodates the control unit of the X-ray machine. Thus it is certain that at least one lead apron and one pair of gloves will be taken to every installation where the X-ray machine unit is to be operated. The United States Army does not suggest but it enforces the wearing of a lead apron and lead-impregnated gloves for this work. Samples of these items are tested and unless their quality is up to a standard, including the requirement that a single thickness of either provide for protection equivalent to 0.5 millimeter lead, these items are rejected. The supporting straps of the aprons provide for suspension from one shoulder to the opposite hip, rather than the neck-band type, thus providing for the maximum of comfort in the wearing of these rather cumbersome garments. The standard gloves have a length of 37 centimeters rather than the somewhat shorter glove which is commonly used in many clinics.

i. Limitation of protection by lead aprons and lead-impregnated gloves. It is important to realize that if one were to attempt to provide complete protection from the X-rays used in roentgenoscopy, it would be necessary to incorporate lead or other opaque material of twice the thickness and weight ordinarily incorporated into lead-impregnated aprons or gloves. Such an addition would result in uncomfortable weight and impractical rigidity and it is believed that not a few radiologists would be annoyed by the use of them. Too many would discard them and expose themselves unduly. The lead apron is intended to protect against secondary radiation. No one should expose himself, even behind a lead apron, to the primary beam. Neither should the hands be subjected to the primary beam, even though protected by lead-impregnated gloves. The amount of radiation which actually traverses an interposed portion of the body of a patient and, thereafter, a thickness of a lead-impregnated glove such as supplied to the United States Army would be minimal, and from all testings it appears that even after a strenuous day barely a threshold dosage of X-radiation would be incurred by the tissues of the hands; nevertheless, it must be recognized that some of the X-rays definitely do penetrate these protective gloves, and every effort should be made to accomplish manipulations by the gloved hand in a position peripheral to the actual limits of the primary beam.

j. Checking as to X-radiation exposures. A quick analysis of the escape of X-radiation into one or another portion of a room wherein roentgenoscopy or other types of roentgenographic activity are conducted can be accomplished, when the room is darkened, by merely positioning a fluoroscopic screen toward the source of the radiation and by testing as to the penetration of the rays by placing an object of varying densities between their source and the fluoroscopic screen. Every roentgenologist should conduct such a survey with his equipment in order to put him on guard. A better method would be that he and his assistants wear a dental film (with the emulsion side away from the body) having a lead number of metal object fixed to the outside of the film packet. Such a film should be processed after a week or so. If the metal object is visualized on a background of dense blackness, it can be realized that at least 2 r– have been received, which value over a period of 5 or 6 days must be considered excessive. It should be routine practice that a platelet count and white blood cell count be obtained on all who operate X-ray equipment, at least once every 3 months. These studies should be made immediately upon hearing of complaints such as fatiguing easily or noting lack of application to duty by the personnel. In general, the same regard should be given to those who are constantly subjected to small quantities of X-radiation as would naturally be given to professional blood donors. Such individuals should have exercise in the open during at least two afternoons a week and they should see to it that their diet is well balanced, including green vegetables and meat. Liver, kidney, and heart should be frequent items in their menu.

CHAPTER 6

AUXILIARY ROENTGENOGRAPHIC EQUIPMENT

SECTION I. FILTERS, DIAPHRAGMS, CONES, AND CYLINDERS

105. GENERAL. Though the life span of roentgenology is less than 50 years—exceedingly short compared to other branches of medicine—numerous devices are now available for the improvement of roentgenographic and roentgenoscopic results. In the early days of the profession, a well equipped X-ray laboratory contained the X-ray machine, a lot of wires, and an ordinary bed, or perhaps a wood table, chair, or stool. Such a room would appear bare indeed beside the modern roentgenographic laboratory. There were no supportive appliances such as technicians enjoy so abundantly today. Though these appliances are not essential for the production of roentgen rays and roentgenograms, they are important because intelligent recourse to them adds symmetry and elegance to the results. Some of the more practical appliances include filters, cones, cylinders, and diaphragms.

106. FILTERS. Filters are thin sheets of material, placed between the tube and patient, through which the roentgen rays must pass before they reach the film. Filters absorb some of the soft undesirable radiations, depending upon the nature of their material. Filters are usually a combination of materials, part of which are built permanently in the tube head and the rest are added or taken away as desired. The former is called the inherent filter of the machine. The inherent filter is attached permanently and is never changed unless a major alteration is made in the equipment. The inherent filter includes the glass wall of the tube, oil which surrounds the tube, and the wall of the tube head. These materials are made thin over the area (window) penetrated by the X-ray beam. In the United States Army Field Unit, these materials are equivalent to 0.5 millimeter of aluminum. This figure is the inherent filtration of this particular unit. Immediately below the "window" of the tube, and attached externally to the tube head, is a channel for accommodating other added filters. In the roentgenographic units such filters are thin sheets of known thicknesses of aluminum; while for therapy units, aluminum, copper, tin, and even lead filters may be added. Filters, regardless of type, absorb some radiations of all wavelengths. They absorb, however, relatively more of the soft rays (longer wavelengths) than hard rays (short wavelengths). Therefore, they have the effect of increasing the average penetrating power of the beam. Thus, the very softest radiation, which might produce undesirable reactions by absorption by the patient's skin, are eliminated by the filter. The use of filters will permit a greater number of repeated exposures to a particular skin area without injurious effects. Filters are especially useful in radiation treatment of patients. For ordinary roentgenography filtration to the equivalent of 0.5 millimeter thickness of aluminum should be provided; for roentgenography about the head and for all roentgenoscopy, the filtration should be of equivalence of no less than 1.0 millimeter thickness of aluminum. (See table IX, app. V.)

107. DIAPHRAGMS, CONES AND CYLINDERS. **a.** When roentgen rays penetrate into the body tissues and are partially absorbed, a variety of atomic events occur. Secondary rays pass out of the tissues in all directions. It is as if many tiny tubes, operating at numerous kilovoltages, were embedded at random in the body and each were sending out its own radiations in its own directions. Some secondary radiation will be emitted in the direction of the film. Thus, objects in the primary radiation beam will be projected as multiple shadows on the film, the principal shadow being due to the unscattered primary rays; the other shadows resulting from secondary rays. If all of these shadows of the same object were equal in size and exactly superimposed, then secondary rays would have no deleterious effect. Unfortunately, this is not true. The shadows are not superimposed; they are not of equal size. Therefore, the principal shadow is not sharply outlined, but is blurred and "fogged" by the extraneous ones.

b. The "fogging" effects of secondary radiations can be kept within permissible limits by reducing the size of the radiation beam as small as possible. It is a general rule of roentgenography to use the smallest X-ray beam which will cover adequately the anatomical parts under examination. The size of the beam is kept within desired limits by the use of cones, cylinders, and diaphragms. (See

fig. 75.) These appliances are made of heavy metals so that all radiations, except the central beam, are absorbed. Cones and cylinders are attached to the roentgen-ray tube head. A selection of sizes, both with regard to diameter and to length should be available. Diaphragms consist of flat sheets of metal (lead) with appropriate size apertures cut in their centers. The size of the aperture depends upon the area of the film to be covered and the anode-film distance. The diaphragm is placed in a slot below the portal of the X-ray tube. These appliances, while restricting the primary rays to small beams, actually reduce the sum total of secondary radiations. They should be used whenever practicable and in the event a cone is not available. The diaphragm may also be placed between the patient and film. In this case it serves as a mask.

SECTION II. GRIDS

108. GENERAL. Grids are auxiliary roentgenographic devices, placed between the patient and the film to minimize the amount of secondary radiation which reaches the film. (See fig. 76.) There are two types of grids—stationary and moving. Either type

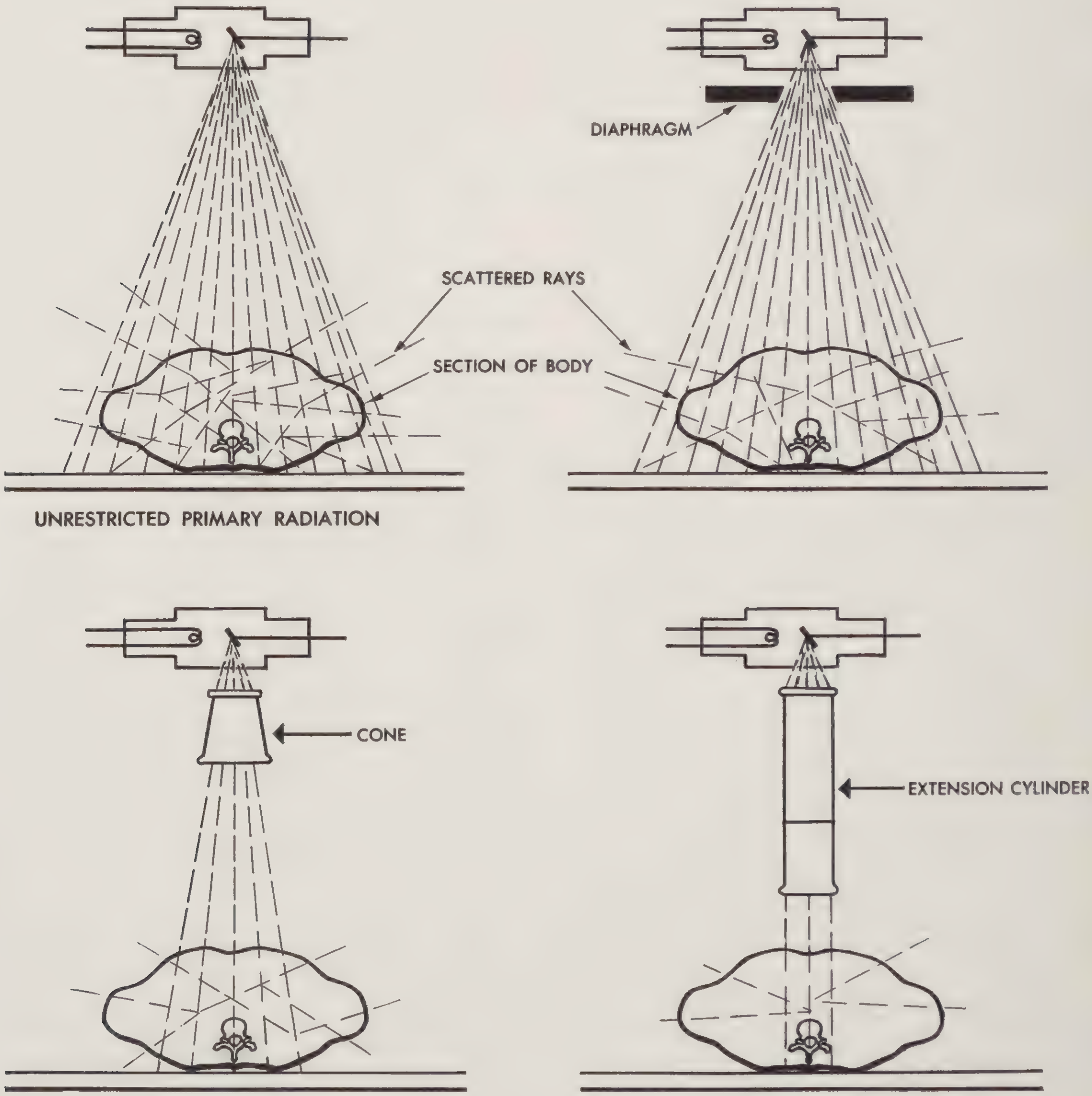


Figure 75. Devices for the reduction of scattered radiation.

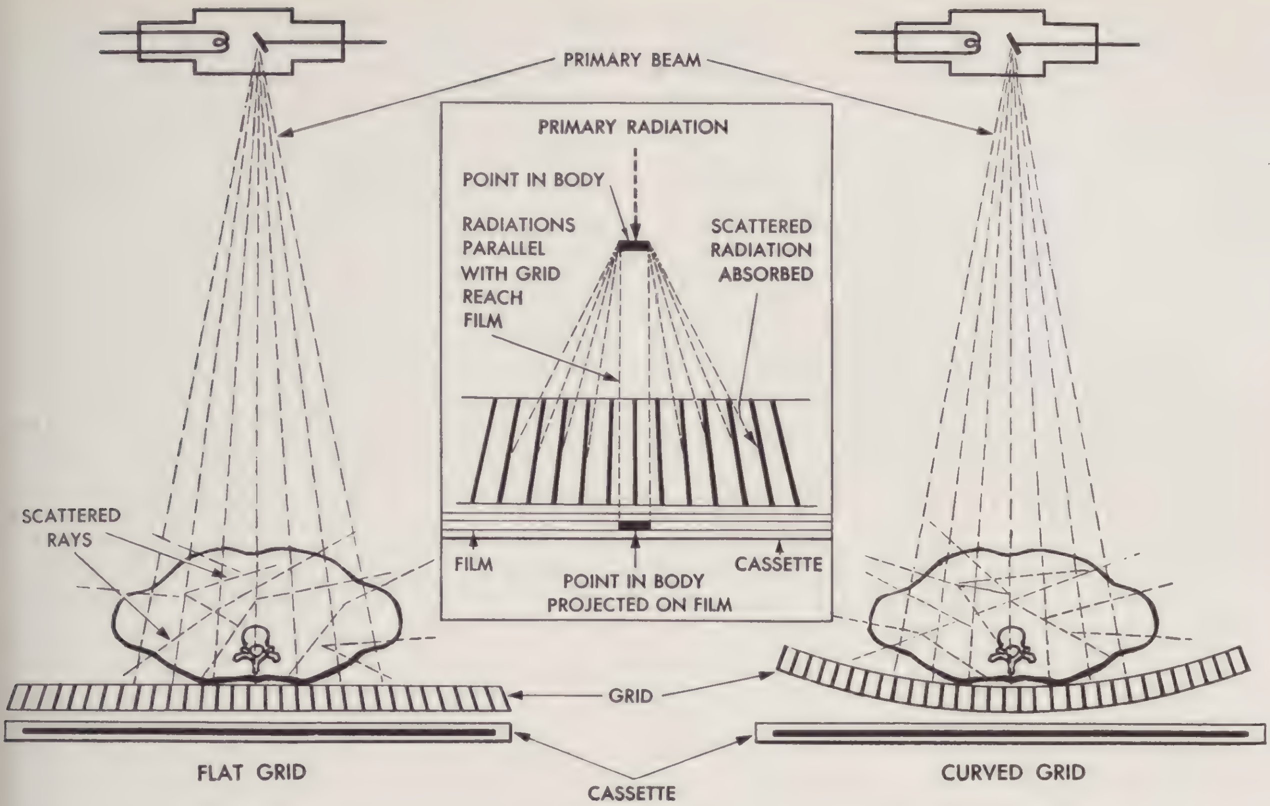


Figure 76. Use of grid to reduce scattered radiation.

may be curved or flat, focused or unfocused. Grids are used in either roentgenography or roentgenoscopy. The modern grid is about 2 feet square and ½ inch thick. It appears to be a solid piece of metal; actually, it is composed of alternately arranged strips of lead separated by relatively radio-transparent materials such as wood or bakelite. Grids will differ from each other depending upon the number of lead strips per inch, their grid radius and grid ratio. The efficiency of minimization of secondary radiation is largely dependent upon the number of strips per inch and the grid ratio.

109. STATIONARY GRIDS. Stationary grids are sometimes called "wafer" grids. The lead strips may be either focused or unfocused and the entire grid may be of the flat or curved type. In a focused grid all of the lead strips, except those in the very middle, are inclined at an angle. The number of lead strips per inch may differ depending upon the design and construction. The U. S. Army Wafer Grid has about 55 lead strips per inch. With Items Nos. 96145 and 96215, the grid may be attached to the fluoroscopic screen thereby enhancing definition of the screen image. The curved type of grid is interesting only as a matter of historical development. It is not commonly used, having been displaced by the more simple and practical—flat grid. However, it is used in photoroentgenography in order to minimize the part-grid and grid-screen distances. The focused grid must be used with one particular side toward the patient and X-ray tube. The proper side, marked on the top surface is that side in which the edges of the lead strips are closest together. If the other side of the grid is placed toward the patient and tube, practically all the radiation will be absorbed; exposure occurring only in the middle portions of the film.

110. MOVING GRIDS. The moving grid, more commonly referred to as the Potter-Bucky diaphragm, has all the characteristics of the stationary grid except that it must move across the film during the time of X-ray exposure. In the original grids as few as 15 lead strips per inch were used. With this grid in the stationary position, the thick strips of lead and nonopaque material produced onto the roentgenogram alternate streaks of high and low densities (grid lines) which were disturbing factors in the visual examination of the film. The term "Potter-Bucky" is derived from Doctors Potter and Bucky who developed the moving grid in order

to eliminate the undesirable grid lines. The "bucky" travels transversely to the table top. It is propelled by a mechanical means which can be adjusted for various speeds. As a matter of convenience, the release mechanism of the "bucky" is often connected into the timing circuit of the X-ray machine. Grid lines, or the appearance of wooliness in the roentgenogram, may be caused by careless or defective operation of the moving grid. The following conditions may produce grid lines:

a. Failure of the grid to move.

b. Jerky grid movement.

c. Uneven thickness of grid strips.

d. Poor alignment of the X-ray tube, laterally or vertically, (improper focal grid distance), in relationship to grid radius.

e. Exposure of the film before the grid begins to move.

f. Exposure of the film after the grid has stopped.

g. When synchronism occurs between ray emission and grid strip position. Ray emission is not uniformly continuous but occurs in discrete impulses per second. Thus, it is possible that the position of the lead strip is exactly synchronized (or in step) with the impulse. This condition occurs in short exposures. The roentgenogram appears as though the grid were stationary.

111. GRID RADIUS. The grid radius is the distance from the center of the grid to a point where the projected planes of the focused strips of the grid would meet. The lead strips of flat grids are inclined at progressively larger angles as they are situated farther from the center strip. (See fig. 76.) Imaginary lines, drawn parallel to the lateral surfaces and perpendicular to the lengths of the strips would meet at a focal point above the grid. Grid radii or 30, 36, and 48 inches are of conventional usage. If the focal spot of the X-ray tube is at the focus of the grid then the divergent beam of primary rays is parallel to the lateral surfaces of the grid strips in the case of the focused grid. Thus, a minimum of primary rays are absorbed by the grid. With the unfocused grid, the radius would be infinity because the lead strips are exactly parallel to one another. (See fig. 70.) Since there is absorption by the grid, shadows of its laminated structure are visible on the roentgenogram in the case of a stationary grid. The presence of grid lines in this situation does not materially detract from the diagnostic value of the roentgenogram. The U. S. Army Wafer Grids are constructed to a radius of 30 or 36 inches. In either instance, the focal-film distance may be decreased as much as 15 percent or increased as much as 30 percent without appreciable "cut-off."

112. GRID RATIO. The grid ratio is the ratio of the width between the lead strips (space occupied by the nonopaque material) to the height of the strips. A common grid ratio is 5 to 1, but grids are constructed with a 3 to 1, 6 to 1, 8 to 1, and occasionally even 12 to 1 ratio. The U. S. Army Wafer Grid has a 5 to 1 ratio.

113. GRID EFFICIENCY. The grid efficiency refers to the amount of maximum absorption of secondary as compared with minimal absorption of primary radiation. When the amount of secondary radiation reaching the film is materially reduced without there being an appreciable absorption of the primary radiation, the grid efficiency is high. With a 5 to 1 ratio grid, approximately 85 percent of the primary rays are permitted to pass through while it absorbs about 88 percent of the secondary rays. Grids of higher ratios as 8 or 12 to 1, have the advantage of absorbing more secondary rays, but they also have the disadvantage of absorbing more of the primary rays. The higher the grid ratio the greater will be the required compensation in milliampere-seconds. A grid functions most efficiently at a tube-grid distance which is equal to the specified radius of the grid.

SECTION III. SUPPLEMENTARY ACCESSORIES

114. ANGLE BOARDS. Accurate angling of the anatomical part with respect to the film is often necessary in order to project the desired shadow on the film. This is particularly true in roentgenography of the head. Many times the desired projection might require that the patient be in an uncomfortable position. In order to assist the patient to maintain these positions, devices called "angle boards" are used. Angle boards provide supportive surfaces at fixed or adjustable angulations with respect to the table top. Angle boards of 15° and 23° are used extensively in sinus, lateral mandible, and mastoid roentgenography. There are other special boards, such as the 17° board with opening for the nose which is used in reverse for the Granger position. These devices assist immobilization of the part under examination.

115. IMMOBILIZATION DEVICES. Elimination, or at least reduction to a minimum, of all motion during the exposure is important. Motion produces unsharpness of the image. Merely instructing the patient to be quiet is not sufficient, particularly in the case of children or the critically injured and uncooperative. In order to overcome the troublesome effects of involuntary motion, such as respiratory motion, short exposure times are necessary. Several methods are devised to prevent voluntary motion. The most common is the use of sand bags. Cloth sacks, filled with sand and varying in weight, are placed over or under the part to be roentgeno-

graphed. Care in positioning the bags must be exercised in order to avoid sandbag shadows on the film. Strips of cloth, 8 or 10 inches wide and weighted at the ends with sandbags serve as a convenient method of supporting the patient in a fixed position. More elaborate roentgenographic tables are often equipped with special brackets and cranks for tightening the fixation bands about the part. Special head clamps with cork guides, and other simple means are employed. An attendant may be required to hold the patient in an immobile position during roentgenography. *Under no circumstances should the technician hold the patient.*

116. CASSETTE CHANGERS. A cassette changer is a device employed in roentgenography whereby the film can be replaced with another without disturbing the position of the patient. The usual type of cassette changer is constructed for vertical chest roentgenography. It accommodates two cassettes which may be placed in the path of the X-ray beam by electrical or mechanical means. A simpler method makes use of a device known as a cassette tunnel.

117. STEREOSCOPIC SHIFTING MECHANISM. Stereoscopic shifting mechanism consists of various designs depending upon the roentgenographic requirements. (See par. 254.) The mechanism may be operated manually or electrically, for a vertical or horizontal shift. By means of properly connected circuits, coordination of the tube shift and cassette shift may be accomplished.

CHAPTER 7

X-RAY FILM, EXPOSURE HOLDERS, AND DARKROOM PROCEDURE

SECTION I. X-RAY FILMS, EXPOSURE HOLDERS, AND INTENSIFYING SCREENS

118. GENERAL. All X-ray films are composed of a light transparent base, coated on one or both sides with a gelatinous emulsion containing a suspension of a silver halide. Double coatings of this emulsion are found on all except certain dental films and those films which are intended for photoroentgenography. In general, a double coating ("duplitization") serves to reduce exposure time requirements. It also increases the contrast. When sensitized with fluorescent light (that is, with intensifying screens or the fluorescent screen of a photoroentgen camera), because of the thicknesses of the two emulsions and the spacing between the emulsion layers, less sharpness of detail is obtainable with the double emulsion film as compared with the single emulsion film. The base of these films is composed mainly of cellulose acetate. Small percentages of nitrocellulose (3 percent or less) are incorporated to provide pliability and to improve transparency. This is the constituent which was responsible for the high degree of combustibility in the films of a decade or more ago. With the low percentages of nitrocellulose in the modern film, there is very little hazard of combustion though the films will burn at a rate similar to or less than that of ordinary paper. These slow burning characteristics have developed for this film the name of "safety" film.

119. EMULSION CHARACTERISTICS. Film emulsions may vary not only with consideration of differences in composition, as produced by one manufacturer versus another, but even as far as any one manufacturer is concerned. For instance, films produced by any one manufacturer may be either of two general types: a "screen" film which is especially sensitive to the fluorescent light of intensifying screens and not so sensitive to direct action by X-rays; and a direct exposure film, which is more sensitive to the action of X-rays and not so sensitive to the wavelengths of fluorescent light such as emitted from intensifying screens. The screen film is the one most commonly used. Film emulsions may differ also as to size of grain of the silver salts. It is generally true that the larger the grain size, the faster the sensitizing characteristics but the less sharp is the detail obtainable. Sensitization characteristics may be represented graphically. (See fig. 77.) The steeper the slope of sensitization (that is, the shorter the gradation of it), the greater will be the over-all contrast on the roentgenogram for any set of technical factors. Steps of gradation may be demonstrated by means of an aluminum ladder. This may be made up with one to three or more millimeters thickness (aluminum) per step, each step having area dimensions of approximately 1½ by 3 inches. Such a ladder might be placed over a film (contained in a cardboard holder) and subjected to an exposure (such as provided with 60 kvp, 10 ma-sec at a distance of 30 inches). This test might be repeated, having the film in a cassette with intensifying screens (reducing the exposure, accordingly). Considerable variation will be noted in the range of roentgenographic densities (that is, contrast), depending upon the kilovoltages as well as upon the use of cardboard holders versus intensifying screens.

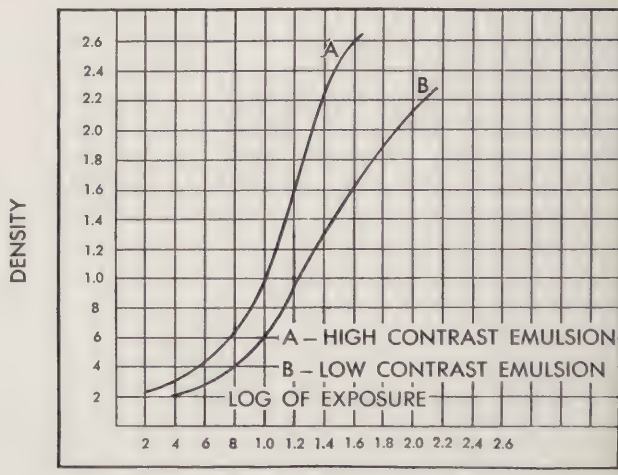


Figure 77. Film sensitization curves.

120. SIZES. Standard dimensions of X-ray films, as used for medical purposes, include 1¼- by 1⅝-inch (dental); 2¼- by 3-inch (dental); 5- by 7-inch; 8- by 10-inch; 10- by 12-inch; 7- by 17-inch, and 14- by 17-inch. All of these are used in ordinary roent-

genography. When indirect exposures are to be accomplished, as in photoroentgenography, depending upon the design of the camera, there may be used: a 35-mm roll film; 4- by 5-inch cut film or 4- by 10-inch cut film.

121. HANDLING OF X-RAY FILMS. The amount of film stored should be of sufficient quantity to meet normal needs. Storage of excess quantities of films should be avoided. The films should be stored in such a manner that they are not subjected to undue pressure caused by piling of the cartons on top of each other. The cartons should be placed on end. If X-rays or gamma radiation are present, suitable lead lined storage bins (Item No. 96055) should be used. Under no circumstances should films be stored in the vicinity of drugs, or sources of volatile gases. Fogging of the emulsion, because of excessive heat, must be counteracted. For tropical climates, films are packed in a wax or paraffin container to protect the emulsion. When film is handled in the darkroom, care should be taken to avoid causing defects in the emulsion by creasing, buckling, and undue pressure. They should be grasped by the corners. The fingers must not be moist or contaminated with the processing chemicals. In order to avoid static discharges onto the emulsion (app. I) the films should never be removed rapidly from cartons or exposure holders. The proper storage, handling and disposal of X-ray film at Army installations is prescribed in AR 850-65.

122. EXPOSURE HOLDERS. a. An exposure holder is a lightproof container used to envelop the X-ray film during the exposure. There are two types of such containers: cardboard holders and cassettes with intensifying screens. For military use, the following sizes are available for standard use: 8- by 10-inch; 10- by 12-inch. In addition, 14- by 17-inch cassettes are obtainable.

b. Cardboard holders function in much the same manner as do ordinary envelopes. In loading a film into the cardboard holder, the protective black paper should be left about the film. The open end of the black paper about the film should be placed at the hinged portion of the paper apron. It is important to fold the apron portion of the flaps first, then the sides and finally, the end. (See fig. 78.) The cardboard holder is composed of two pieces of ray-transparent paper-board hinged together with binding cloth. One of the cardboard covers contains a thin layer of lead foil which serves to absorb back-scatter from the table top. Hence, this cover should be positioned *away* from the X-ray tube. The proper side of the cardboard holder is usually identified: "Tube Side—This Side Up."

c. Cassettes with intensifying screens serve the same purpose as cardboard holders except that they shorten the time of exposure required to a fraction of the original time, as compared with cardboard

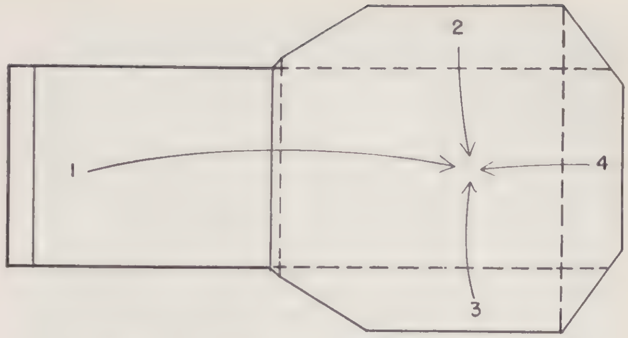


Figure 78. Proper folding of cardboard holder.

holders. The cassette consists of two intensifying screens inclosed within a hinged bakelite and metal cover. The front screen is thinner than the back screen in order to allow for less absorption.

123. INTENSIFYING SCREENS. a. General. Intensifying screens are composed of a special cardboard base having a coating of fluorescent crystals such as calcium tungstate or zinc sulphide held together by a binding substance. X-radiation produces fluorescences of the crystals. This fluorescence is used to sensitize the emulsion in conjunction with the X-radiation itself and therefore the black separating paper used in packing should be removed before placing films in cassettes which contain intensifying screens. The fluorescent surfaces of the screens are positioned in immediate contact with the film, one being above and one being below the film. Some screens contain one thickness of fluorescent crystals, some another. The larger the diameter of the crystals and/or the thicker the layer of the fluorescent salts, the more intensely fluorescent the screen. The desirable features of an intensifying screen are: maximum speed, uniformity of speed, maximum sharpness, minimum phosphorescent lag or afterglow, maximum stability, good cleanability, and wearing qualities.

b. Types. Intensifying screens are produced by several manufacturers. They are identified as to relative speeds by means of trade names. In general, there are three grades: slow, medium, and fast. For roentgenography calcium tungstate crystals are used as the fluorescent crystals of the intensifying screens. Medium speed screens are routinely used for general roentgenographic requirements. The fluoroscopic screen is used for visualization in roentgenoscopy. This type of screen usually consists of zinc sulphide crystals. In addition to its fluorescent qualities, that is, emission of light during activation by X-rays, this screen also has an afterglow or phosphorescence. This afterglow is more commonly referred to as "screen lag." Phosphorescence is the emission of light by crystals after the activating sources have ceased. This afterglow is not ordinarily serious

enough to interfere with the requirements of roentgenoscopy. However, a good intensifying screen must possess minimum of afterglow. A fluorescent screen, "Fluorazure" is incorporated in the photoroentgenographic unit. It consists of zinc sulphide crystals.

c. Speed. The speed of an intensifying screen refers to the amount of fluorescent light it emits relative to the intensity of X-radiation to which it is exposed. Medium speed screens require a 25 percent increase in exposure as compared with fast speed screens to produce the same film density. Likewise slow speed screens will require approximately 60 percent increase in exposure time. If the arbitrary value of 1 is given to fast speed screens, the relative speed of medium screens will be 1.25 and for slow speed screens 1.6. Hence, the designation; slow, medium, and fast screens. For routine roentgenography, medium speed screens meet most of the requirements. Medium speed screens are the standard item of supply. This one speed of screen has been standardized in order to counteract wastage of films because of errors in exposure compensations which might be due to interchange of types. In addition, medium speed screens have all the desirable characteristics for short exposures and produce satisfactory sharpness of the roentgenographic image. The speed of intensifying screens is affected by the quality and quantity of X-radiation to which it is exposed as well as by age, temperature, thickness of the crystal layer, and the grain size.

d. Intensification factor. The intensification factor is the ratio of the exposure required to produce the same film density without intensifying screens to that exposure required with intensifying screens, all other factors being constant. For an example, if 1 second is required to make a roentgenogram with fast screens and 30 seconds is required to obtain the same roentgenographic density without screens, all other factors being constant, then the intensification factor is 30, for the screens used. If medium speed screens are used requiring 25 percent more exposure than fast speed screens, then the intensification factor in this case will be approximately 25. If slow speed screens are used, 60 percent more exposure will be required than fast speed screens, then the intensification factor will be approximately 15. With all three types (that is, speeds) of screens, the intensification factor varies markedly and directly as the kilovoltage is increased. Medium speed screens for usable roentgenographic kilovoltage values have an average intensification factor as follows:

Kvp	30	40	50	60	70	80	90
Intensification Factor	6	12	15	20	25	30	35

Medium speed screens of different manufacturers vary from the above values. However, the intensification factors indicated may serve as a general guide. It is not necessary to calibrate each individual pair of screens of the same type produced by the same manufacturer. (See par. 89.) For practical purposes, the intensification factor of the same type of screen (that is, slow, medium and fast) will produce the same relative film density.

e. Mounting. The thinner screen is affixed to the front of the cassette and the thicker screen to the back of the cassette. The thin screen is placed nearest the X-ray tube because it absorbs less of the X-ray energy. When a film is loaded into a cassette the screens must be in close contact with it in order to prevent "fuzziness" and unsharpness of the image. A simple test to determine proper screen contact is to place a piece of wire mesh on the cassette loaded with a film. A flash exposure is made and if proper contact exists between the screens and the film then the outline of the wire mesh will be sharp throughout. (See fig. 79.) If the outline is fuzzy and some areas possess varying degrees of sharpness, then there is poor contact. This condition may be remedied by inserting pieces of felt or paper under the back screen until the maximum sharpness is obtained.

f. Care. Care should be taken to avoid scratches, dirt particles, abrasions, and finger prints on intensifying screens. When loading a film in a cassette with intensifying screens, care should be taken to avoid scratching the screen with the edge of the film. A special coating is usually applied to the screen surface by the manufacturer to protect it against damage. If dirt or other markings occur on the screen, a solution of mild soap (Ivory) and water should be applied with a wad of cotton. The surface should be cleaned gently and the cassette should remain open, in a dust free location until completely dry. If the screens are not properly dried and the cassette is closed, peeling of the crystal layer will occur. *Common cleaning fluids should never be used.* Periodic dusting of the screens with a camel's-hair brush is recommended.

SECTION II. DARKROOM PROCEDURE

124. PROCESSING ROOM. a. General. The first essential of a processing room is that it be lightproof and X-ray proof sufficiently so that films contained therein will not become fogged.

b. Lightproof features should be checked frequently. A simple method to locate light leaks is to place dental films, half covered with black paper, in various locations of the room with conditions of darkening as for ordinary activities. These test films should be placed particularly where films are normally loaded and unloaded. They should be exposed for periods of at least three times the normal loading or unloading time requirements. Thereafter, they should be processed through developer and fixer in the usual manner. Any visible degree of fog

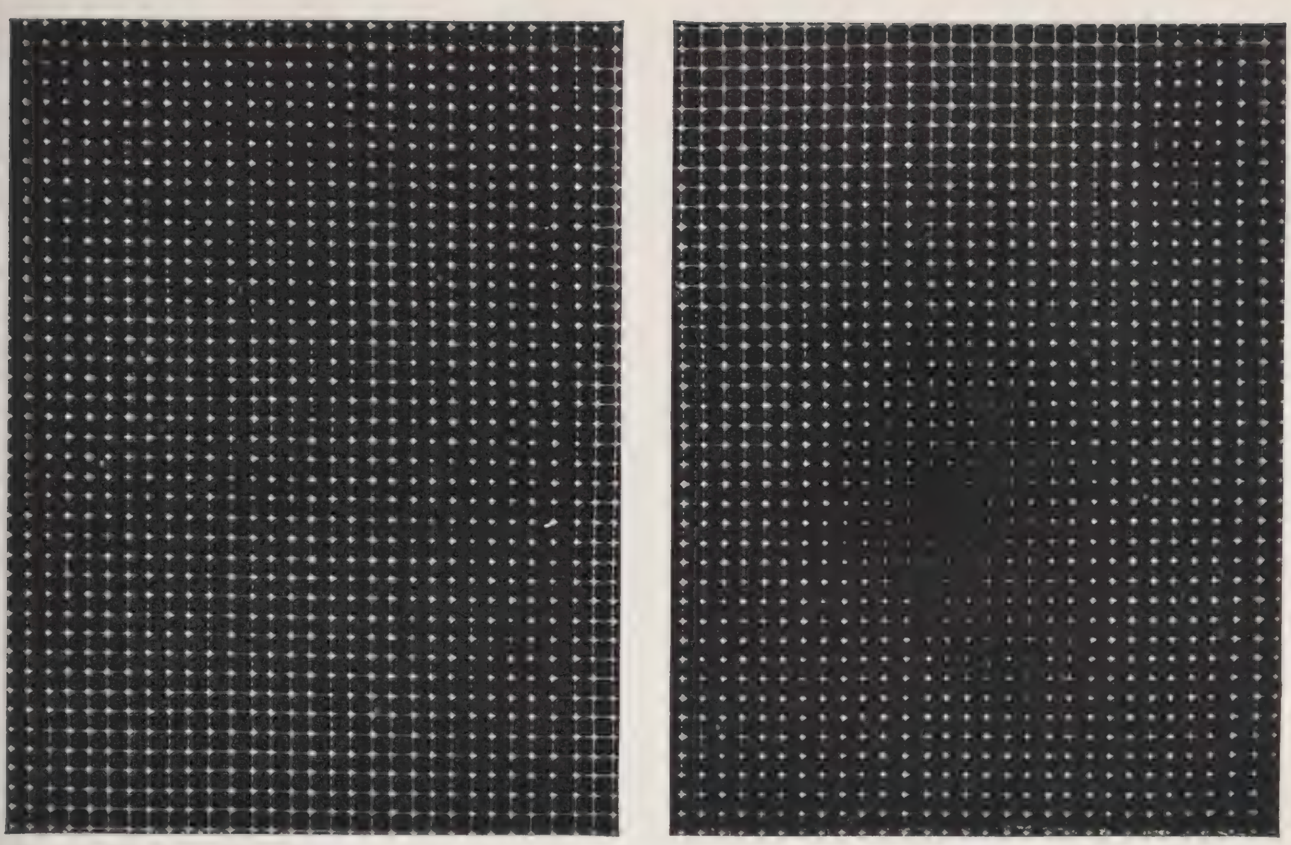


Figure 79. Testing for screen contact. (a). Roentgenogram of wire screen showing good intensifying screen contact. (b). Poor intensifying screen contact.

in that portion of the film not covered by the black paper is indicative of light leaks. The practice of covering only one-half the film with the black paper is especially practical for the testing of light fog as compared with other factors which might produce fog. Light leakage can be considered blamable only if the uncovered portion of the film is fogged in contrast to the covered portion of the film; the latter showing no evidence or very little evidence of fogging.

c. Roentgen ray proof features. The processing room must be protected against the ingress of X-radiation. To some extent, this can be accomplished by insisting upon certain arrangements of the X-ray machine in the exposure room. For instance, the X-ray table should not be positioned immediately adjacent to the inside wall of the processing room; auxiliary apparatus such as cassette changers, photoroentgen camera units and similar equipment should be positioned along an outside wall so that when using them, the primary beam of X-radiation will be directed toward an outside wall. Likewise, when accomplishing oblique projections, the patient should be positioned onto the X-ray table so that the primary beam will never be directed toward the wall of the processing room. In addition to such precautions, however, all walls of the processing room, serving to separate it from an exposure room, should be lined with ray-opaque material such as lead or barium plaster. This must serve as protection not only against secondary radiation but also against primary radiation escaping from the tube housing or such as might be concerned with an improperly directed primary beam. To provide such protection against radiation from a roentgenographic room, ordinarily, a wall lining of no less than 1.5-mm thickness of sheet lead or no less than 18-mm thickness of barium plaster is required. Such protection should extend from the floor level to the ceiling and at least 18 inches from the walls onto the ceiling or about any ducts or shelvings which may extend through the wall. For protection against X-radiation which might be concerned with an adjacent roentgenotherapy room, this protection may have to be tripled or quadrupled. The adequacy of protection against such leakages of roentgen radiation can be checked by exposed film testings comparable to those described in b above. The testings for X-radiation require several days exposure of the film. Moreover, rather than covering half of the film it should be covered entirely with black paper. A ray-opaque object, such as a key or penny, should be placed upon the film. If, after processing such a test film, there be found the image of the key or

penny one can be certain that roentgen radiation is penetrating into the processing room and that many or possibly all of the films stored therein may become fogged. Therefore, the locations where such leakage might be occurring should be sought and these covered with additional ray-opaque substance or corrections otherwise made.

d. Temperature conditions. The temperature of the processing room should not exceed 90° F. This fact emphasizes the importance of not having too many radiators in the darkroom and they are not located in close proximity to sites of film storage. The darkroom should be located on a side of the building where the rays of the sun will not be too penetrating. An eastern exposure is to be preferred or a side of the building protected by shade, particularly during the afternoon. It must be realized that the emulsion of roentgen ray films may become sensitized merely because of heat. To test for such a condition a film may be processed without any preliminary exposure whatever. Visible fogging, of course, may be due to light or roentgen-ray exposure. If the foregoing have been ruled out on the basis of testings such as described in b and c above, it may be concluded that the fogging has been caused by heat, provided that this condition did not exist in the films prior to their storage in the processing room.

e. Wallfinish. It is not necessary that the walls and ceiling of the processing room be painted black. A light color, such as pea green, is recommended for the ceiling and upper half or two-thirds of the side walls. The lower portions of the side walls might be painted brown or grey in order that dirt markings and chemical stains be less conspicuous.

f. Illumination. It is not necessary that X-ray films be handled in total darkness. It should be possible, after a few minutes of visual accommodation, to see all that is going on in a processing room, even while the films are exposed. It is important, however, that the lighting providing for such vision, be filtered. X-ray films are sensitive to the blue violet wavelengths of the light spectrum. Ordinarily, they are not sensitive to the other wavelengths of the spectrum such as orange, red, and green. Filtering of the wavelengths of light to which X-ray films are sensitive can be accomplished with the use of light filters such as No. 2 Red filter and Wratten Series 6B. All lighting which is to be serviceable during film processing should be filtered in this manner. A 10-watt light source is recommended. It is best to use indirect lighting and to provide such by way of ceiling fixtures, rather than wall fixtures. It must be realized that the emulsions of X-ray films which have been sensitized by the use of intensifying screens are more sensitive to darkroom illumination than films exposed without intensifying screens. For this reason, there should be no direct illumination over or near the site where unloading of exposed films is to be accomplished.

g. Arrangement of equipment. It is practical to have the film loading bin and bench on one side of the room and the processing tanks at a working distance sufficient to avoid splashing of chemicals onto the sites where films or intensifying screens might be placed. Racks for film hangers should be provided and located within handy reach of the loading bin. The dryer may be located in the processing room or in a wall duct so as to provide for access to the processed films without having to enter the room. (See fig. 80.)

h. Additional facilities. It is impractical to depend upon an ordinary door, for access to the processing room. With such provision, light leakage frequently occurs about the sill and the door may be opened unexpectedly when films are unprotected. Furthermore, it is not usually practical to arrange for constant circulation of air with a closed door arrangement. In lieu of a door, a labyrinth or maze should be provided for ingress and egress. The width of the passageway should be such, with respect to its length, that light will not be reflected into the processing room. Absorption of the light can be accomplished to a large extent by painting the walls of the labyrinth a dull black color. A bypass box or a film transfer cabinet located in the wall between the roentgenographic room and the darkroom permits cassettes and film holders to be stored or transferred without the necessity of going from one room to another. The cabinet is usually provided with a safety attachment to prevent opening of both doors of the cabinet simultaneously. It is practical to have an air circulating fan in the darkroom. This might be constructed into an outside wall so as to provide for circulation of the air through the room and the labyrinth. Precautions must be taken that the construction of such a fan be lightproof.

125. DARKROOM CHEMISTRY. a. General. Film emulsions become sensitized when subjected to energies such as: ordinary light, ultraviolet rays, roentgen, or gamma rays. Unfortunately, sensitization also occurs to some extent by heat, static discharges, and rough handling. Any such treatment may produce an "activation" of the silver halide crystals. A "latent" image is produced in the areas of activation. In roentgenography, the activation of the silver halide crystals is related to those X-rays which penetrate a part placed upon a film and between it and the X-ray tube. Under such conditions, because of variations in thickness and densities of the interposed part there results a variation of the degree of activation of the emulsion crystals and therefore varying densities of the processed image. The image is invisible until subjected to the processing chemicals. There are five steps in chemical processing: development, rinsing, fixation, washing, and drying.

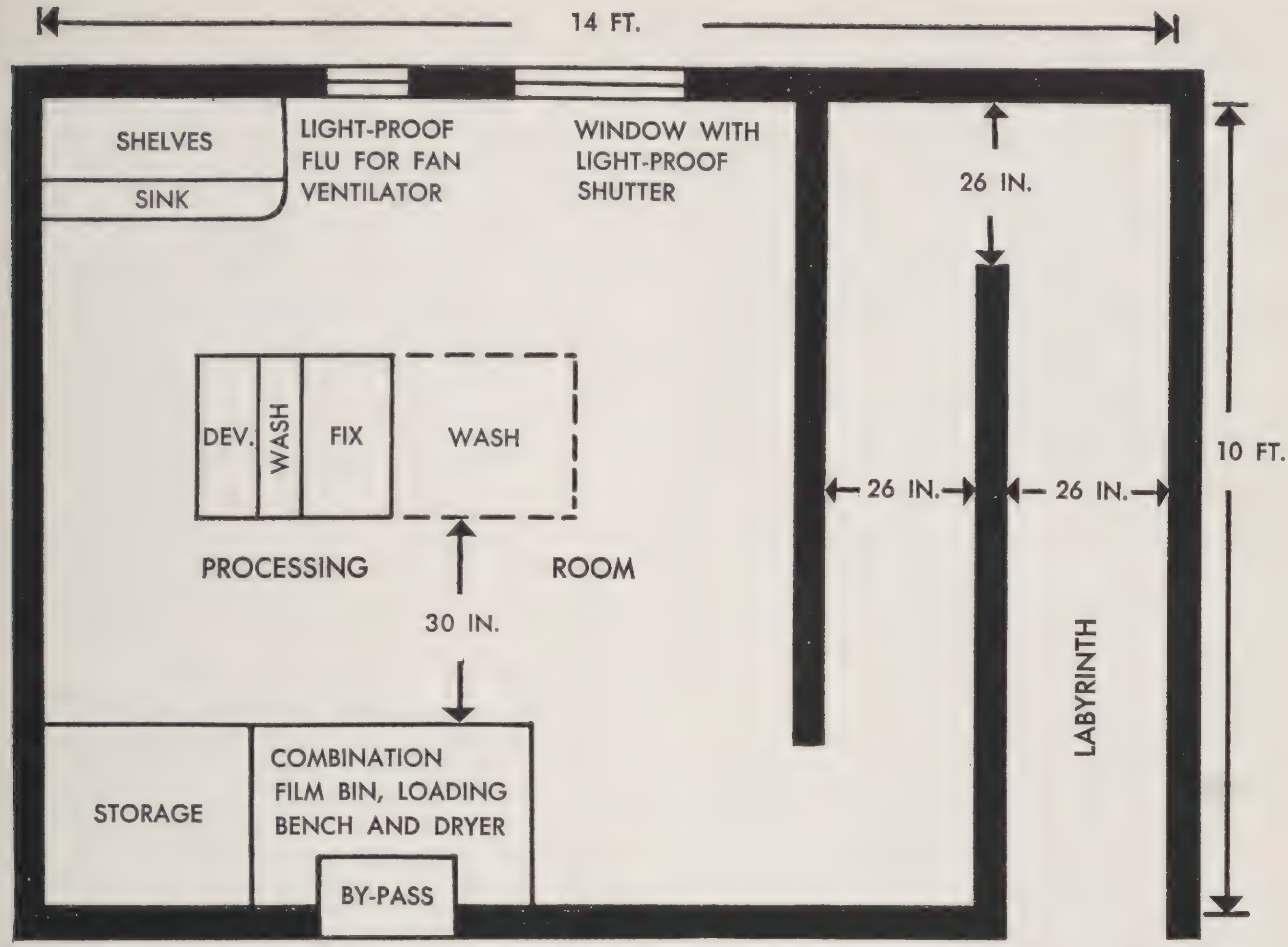


Figure 80. A typical darkroom.

b. Development. Development of the "latent" image is accomplished by immersion of the exposed film in a chemical solution called the developer. The developer consists of reducing agents, activator, restrainer, and preservative. The important ingredients of this solution include: elon (or a substitute), hydroquinone, potassium bromide, sodium carbonate (or a substitute), sodium sulfite, and water. In Army installations the ingredients are issued in prepared powder form. If this supply is not available the developer may be compounded in accordance with the following formula:

Water (125° F.)	2½ gals.
Elon (or metol)	1¼ oz.
Hydroquinone	6¼ oz.
Sodium sulfite, anhy.	4 lbs.
Sodium carbonate, anhy.	1¼ lbs.
Potassium bromide	4 oz.
Water to make	5 gals.

Elon and hydroquinone are the active ingredients. They reduce the silver of those crystals which have been activated to metallic silver. The quantity of reduced silver determines the density of the roentgenogram. Elon acts rapidly and contributes to detail. Hydroquinone acts more slowly and is more concerned with the over-all density and contrast. The chemical activity of hydroquinone is accelerated with high temperature; in fact, it is too active, producing a fogging effect with temperatures above 70° F. With temperatures below 60° F., its chemical activity is markedly decreased and with very low temperatures it may be inhibited entirely. Elon is affected only slightly by temperature. The potassium bromide is included for the purpose of restraining the action of the hydroquinone. Without it, a chemical fog would be produced. During the process of development, bromides are released from the crystals of the inactivated silver molecules and thereby this restrainer concentration is increased. Therefore, the developing time must be increased as more and more square feet of film are processed. The developing agents require alkalinity as an "activator" in order to function. Therefore, sodium carbonate (or some substitute) is included. Too much sodium carbonate produces chemical fog; too little retards development. The sodium carbonate

also serves to soften the gelatin of the emulsion thereby enabling the developing agents to act upon the exposed silver halide crystals. Developing agents have a great affinity for oxygen. When exposed to air, they oxidize readily and thereby lose their usefulness. To retard this oxidation, sodium sulfite is added. It acts as a preservative. As a further protective measure, when not in use, the solution should be covered, preferably with a wooden float. It is imperative that the developing procedure be performed with precision. The solution should be prepared in accordance with the manufacturer's instructions. The developing time should be determined by means of a clock (varying from 4 to 8 minutes, depending upon the age and temperature of the developer) and the temperature of the developer should be maintained at 68° F., plus or minus 2°. The recommended time for development is 4½ minutes at 68° F. For most developers, 1 minute is added to the time after 25,000 square inches of film surface are developed; another minute is added after an additional 12,000 square inches, and a third minute following another 8,500 square inches. Thereafter, the entire solution should be replaced. During the useful period, small quantities of new developer may be added from time to time in order to maintain a level adequate to cover to the top of the suspended films. A "replenisher" (a developing solution not including potassium bromide or other restraining chemicals) is ideal for restoring developer level. While in the developer, films should be agitated at intervals, particularly during the first few minutes. This is done in order to insure the elimination of air bubbles from the surface of the films and to prevent close contact between any two films. Either factor will prevent adequate action of the chemicals and poor development of the areas concerned. It is good practice not to have an illuminator, even with a light filter, adjoining the developing tank because there is too great tendency for the technician to lift the films from the developing solution and check the degree of roentgenographic density. Such a practice is described as "sight development"; it is too oftentimes productive of light fog and streaking of densities.

c. Rinsing. After completion of development, the films should be lifted by their holders and tilted so as to provide for drainage of developing solutions back into the developing tank, for a few seconds. They should then be agitated in a water bath for about 15 seconds. The importance of this rinsing is twofold: it serves to stop further development and it removes most of the sodium carbonate or other alkali—thereby lessening neutralization of the acid in the "fixing and clearing" chemicals (the hypo bath). A "shortstop" bath (one-half of one per cent solution of glacial acetic acid) may be substituted for the ordinary water rinse. More effective neutralization of the developer is thereby accomplished.

d. Fixation. After development, the film emulsion contains, in addition to the reduced metallic silver, all of the silver halide which was not activated by the roentgen rays, but which would reduce to metallic silver if exposed to light. This inactivated silver halide must be removed. Its removal is accomplished with the third step in the processing procedure. The fixation solution consists of the fixing agent, preservative, acidifier, and hardener. The fixing agent is sodium thiosulphate. The fixation bath, more commonly referred to as the hypo bath, also contains an acid such as acetic acid. Its purpose is to completely neutralize the alkali carried over with the developer. It also assists in the function of a third ingredient; namely, potassium alum. The purpose of the latter is hardening of the emulsion—to counteract easy scratching or peeling of it. Just as with the developing solution, sodium sulfite is included, as a preservative to counteract disassociation of the sodium thiosulfate. Removal of the inactivated silver halide crystals is ordinarily accomplished within 3 or 4 minutes but 15 or 20 minutes are required for adequate hardening of the emulsion. The temperature of the fixing bath should be controlled just as that of the developer. Though temperatures above 70° F., hasten the clearing process, such temperatures may produce undesirable softening of the gelatin. With temperatures below 60° F., there may be precipitation of sulphur, resulting in a milky appearance of the solution. Fixation powders are obtainable in prepared form. In the event this supply is not available, the following formula may be used:

Water (125° F.)	5 gals.
Sodium thiosulphate	25 lbs.
Sodium sulfite	1¼ lbs.
Glacial acetic acid	1¼ pts.
Potassium alum	1¼ lbs.
Cold water to make	10 gals.

e. Washing. The importance of adequate washing of films is too seldom appreciated. Final washing must accomplish removal of the hypo and other undesirable chemicals from the emulsion. If this is not accomplished, after drying there may be a murky appearance or even an actual salt deposit onto the film surfaces. Even though such a deposit is not evident, small quantities of residual hypo, invisible to the eye, may be present. Because of the sulphur content of such residual hypo, within a few months or years, there may be produced a yellowish discoloration of the film (due to silver sulphites), and in fact, very complete chemical disintegration may result even to the stage of fragmentation of the film base. Adequate washing must be accomplished to counteract these unfavorable possibilities. The wash water should be clear and of temperatures within the range of 50° F., to 80° F. The water must be circulating. The washing time requirement will vary depending upon the design of the wash compartment,

the rate of water exchange, and the number of films having to be accommodated at any one time. Ordinarily, the rate of water exchange must be 4 to 8 times the capacity of the tank per hour in order to accomplish adequate washing of "screen" films within 30 minutes and "nonscreen" films within 1 hour. The quantity of wash water required and the efficiency of its washing are greatly enhanced with the use of a baffle design of wash tank and a cascade system of water flow, as provided with the U. S. Army Field Unit, Auxiliary Wash Section, (Item No. 96117) figure 57. With this design of wash tank, utilizing a water exchange rate of 4 to 8 times the volume of its final wash compartment, approximately 70 percent of the residual hypo is removed from the film emulsion in the first wash compartment —that located at the drain pipe position. After 5 minutes, the films should be removed from this compartment and placed in the middle compartment. Here, they are subjected to water contaminated less with the chemicals which are to be removed. The water of this compartment serves for washing against only approximately 30 percent of the residual hypo. The films should be removed from this compartment after another 5 minutes and placed into the freshest water. Thus, the freshest water serves to wash the emulsion after most of the residual hypo has been removed. On the basis of this cascade arrangement, the efficiency of washing is so increased that ordinarily practically all of the hypo can be removed from film emulsions within 15 to 20 minutes. Testing as to adequacy of washing can be accomplished in a very simple manner. A single crystal of potassium permanganate may be dissolved in approximately 4 ounces of ordinary tap water. A light pink solution should be obtained. If the color be purplish red or a deep pink, more tap water should be added until a light pink color is obtained. Half of the volume should be kept in one beaker, as a control; the other half, used for the test. After what is believed to be adequate washing, the film should be raised from the wash water and its drippings allowed to fall into the light pink potassium permanganate test solution. If these drippings produce a discoloration of the pink, either to a yellow or a colorless solution, there is the evidence of residual hypo and inadequacy of washing. It must be realized that some tap water contains considerable organic constituents and that these could be responsible for fading of the pink color. Tap water rather than distilled water is suggested merely to simplify the procedure. However, when using tap water, it is always important to check the control solution mentioned above. If that solution has retained its light pink coloration, then discoloration in the testing solution can quite surely be attributed to residual hypo and inadequate washing. This procedure can be used to determine the proper time of washing required for any installation.

f. **Drying.** After adequate washing of the films, they should be suspended for drying. This may be hastened with the aid of a draft of air such as provided with the U. S. Army Field Drying Unit, Item No. 96055. If the room temperature be not above 90° F., it may be practical to include use of the heater. However, if the air be too hot and the films too close to the heater, uneven drying might occur with resultant crinkling of the emulsion.

g. In an average roentgenological department, approximately three-fourths of the film problems are attributable to errors incurred in the processing room. There, the possibilities are numerous as indicated by the tabulation of darkroom "don'ts." (See app. I.)

CHAPTER 8

FUNDAMENTALS OF ROENTGENOGRAPHIC PROCEDURE

SECTION I. ROENTGENOGRAPHIC QUALITY

126. GENERAL. The quality of a roentgenogram may be described in terms of four characteristics: detail, density, contrast, and distortion. These four factors might be considered with respect to any one portion of the image or with respect to the over-all appearance of the roentgenogram. A clear understanding of the effects and significance of each factor will in a great measure determine the roentgenographic quality.

127. DETAIL. Detail pertains to the contour and structural lines of the roentgenographic image. Every roentgenogram has detail; this detail may be either sharply or unsharply defined, hence, the commonly applied term, "definition." Mathematically, detail (d) may be written, $d = D_1 - D_2$, where D_1 and D_2 are densities of points separated by a minimal resolving distance. The sharpness of detail is affected by (fig. 81)—

- Focal-spot size—the smaller the effective focal spot, the sharper the detail.
- Focal-film distance—the greater the focal-film distance, the sharper the detail.
- Part-film distance—the less the part-film distance the sharper the detail. Use of grid increases part-film distance—detracts from detail. Factors 2 and 3 are related to distortion—the greater the distortion, the less sharp the detail.
- Exposure holder—use of cassettes with intensifying screens detracts from detail; the faster the screen (par. 123) and/or the poorer the screen film contact the less sharp the detail. The use of cardboard holders contributes to detail.
- Motion—the greatest deterrent of detail—motion by the patient, motion of the film and/or motion of the tube, anyone may be concerned; even minimal motion such as a shiver or a shake by the patient is sufficient to blur detail.
- Miscellaneous—developer action during first minute by elon (metol) versus hydroquinone. Film emulsion characteristics—the larger the grain size effect the less sharp the detail.

128. DENSITY. Density of a roentgenogram refers to the blackness of the area of the roentgenogram under consideration. In the final analysis, the desirable densities are concerned with the quantity of metallic silver deposited in the emulsion of the film as the result of primary X-radiation exposure and the processing procedure. High degree of density gives a "dark" film; a "light" film has a low degree of density. Technically, film density is defined as the logarithm of the ratio of intensity of white light incident on the film and the intensity of light emerging from the film. Mathematically, density is expressed as $D = \log_{10} I_o/I$, where D is the density. I_o and I are intensities of incident and emergent light, respectively. D is measured by various types of densitometers. The range of useful densities is from 0.3 to 1.8; the average being approximately 1.0—a density which transmits 10 percent of the incident light. Roentgenographic density is affected by—

- Milliamperage—density varies directly and proportionately as the milliamperage.
- Exposure time—density varies directly and proportionately as the exposure time. Therefore, exposure time and milliamperage are interchangeable.
- Kilovoltage—density varies directly and approximately in proportion to the squares of the relative kilovoltages.
- Focal-film distance—density varies inversely as the squares of the relative focal-film distances.
- Miscellaneous—excessive developing time; high temperatures of developing solution increase the density; use of cones, diaphragms and grids decrease it (hence, requiring appropriate compensations).

129. CONTRAST. Contrast refers to the difference between two densities as perceived by the human eye. At least three factors are concerned: the actual difference in densities (as measured by physical means); the gradation of the densities between them and the general density range. For instance, if one density be of a blackness of 1.0 density units and another of a blackness of 1.5 density units, the contrast is greater than in the case of two densities of 1.0 and 1.3 density units, respectively. Considering

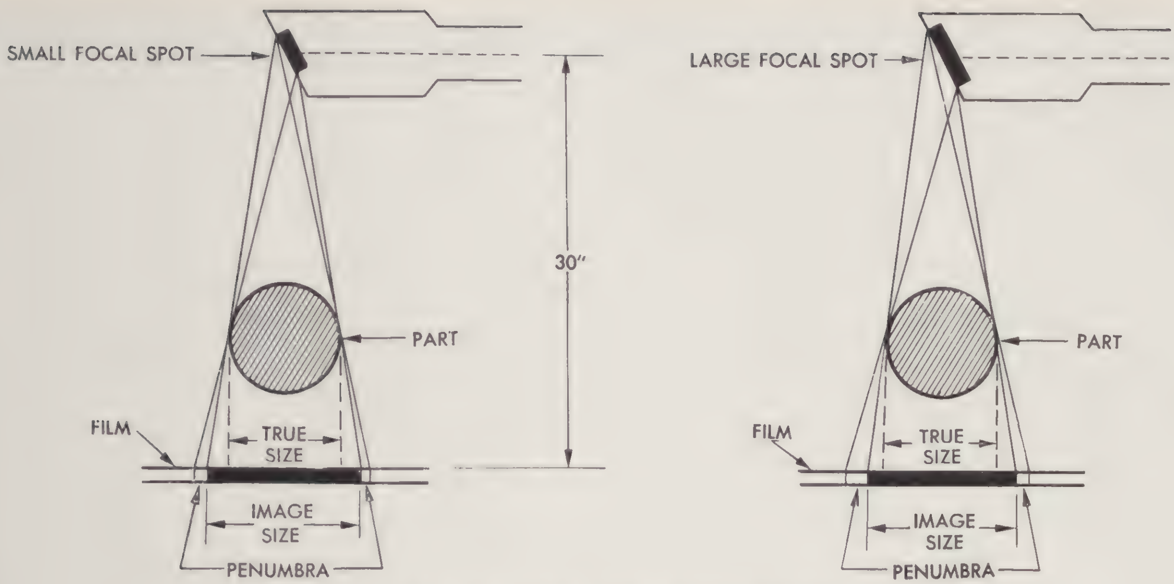


Figure 81(a). Effect of focal spot size on detail.

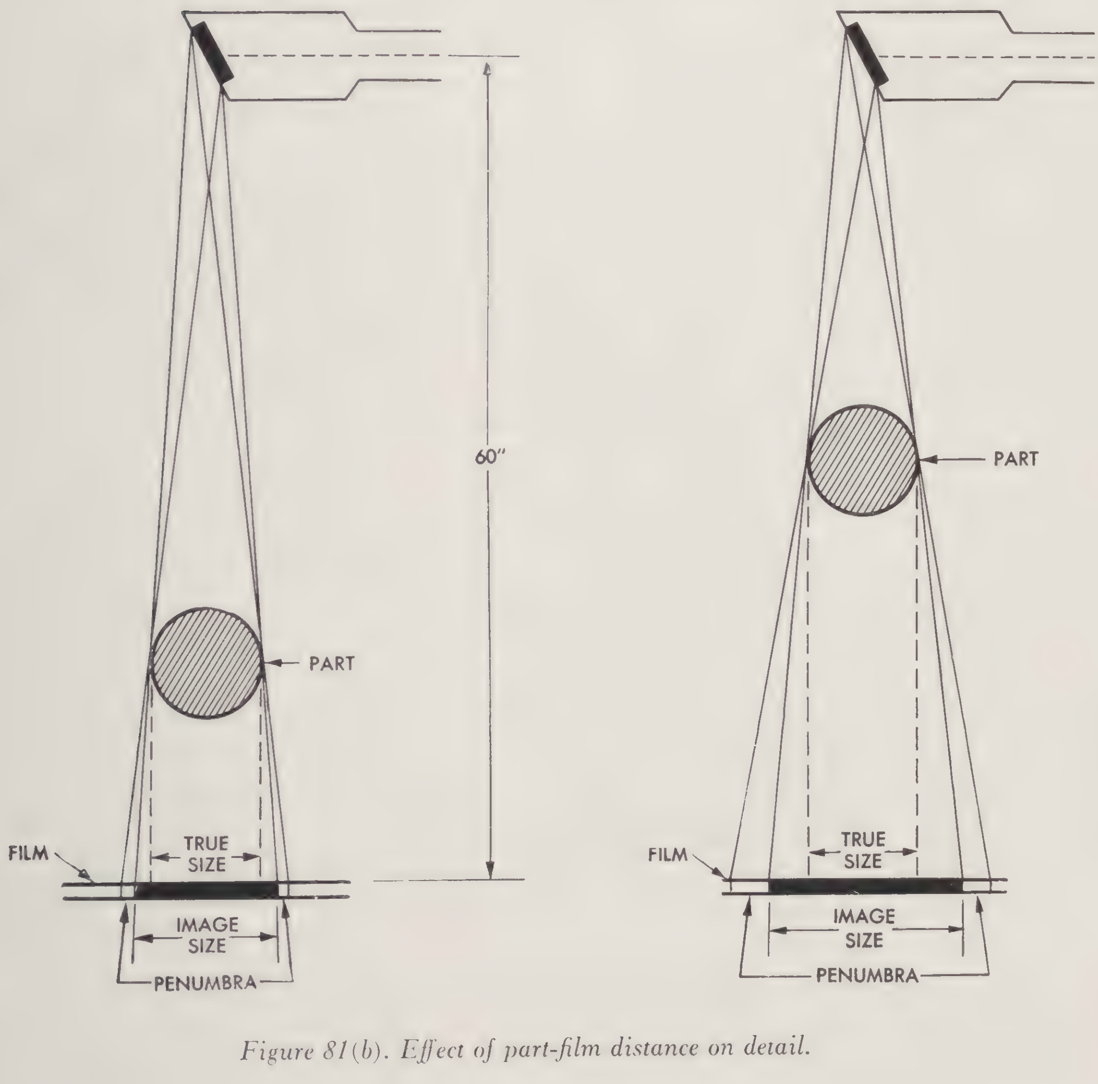


Figure 81(b). Effect of part-film distance on detail.

Figure 82. The effect of cardboard holders and intensifying screens on contrast.

the first two densities again, if they be in close approximation, the contrast will be greater than if they be separated by intervening steps of density. Differences in densities in the light exposure range, below 0.3 density units, and in the heavy exposure range, above 1.8 density units, are difficult to distinguish. Therefore, a density difference as considered above in the range 1.0–1.5 density units is much more evident than in the range 1.8–2.4 density units; that is, contrast is less in the latter situation. Mathematically, contrast can be expressed as, $C = D_1 - D_2$, where D_1 and D_2 are the densities of two different areas of the film. Contrast, in this sense, generally refers to the entire over-all film contrast. Roentgenographic contrast is affected by—

Kilovoltage—the lower the kilovoltage the greater the contrast. It is conceivable that for any one part there may be a kilovoltage productive of X-rays capable of penetrating certain tissues (soft tissues) and not penetrating certain other tissues contained (that is, bone). With such conditions there would be obtained the highest contrast. Thus a certain kilovoltage may accomplish a desirable contrast for roentgenography of the hand but when used for roentgenography of the pelvis, it would result in excessive contrast.

Exposure holder—cassettes with intensifying screens increase contrast. The greater the "speed" of the screen, the greater the contrast obtained. Comparing the use of cassettes with cardboard holders, less contrast is obtainable with the latter. (See fig. 82.)

Miscellaneous—development solutions—warm development or excessive development time will increase contrast. Auxiliary devices—use of filters, cones, diaphragms, cylinders and grids will increase contrast by minimization of secondary radiation; film emulsion characteristics also influence the contrast.

130. DISTORTION. Distortion is the perversion of the true shape of the part as represented on the roentgenogram. The true shape cannot be exactly reproduced since all the structural features of the body are represented in a single plane. Thus, distortion is present in every roentgenogram. If the image is distorted to such an extent that it appears enlarged beyond its true size, then the distortion is referred to as magnification. Distortion is affected by (fig. 83)—

Part-film distance—the less the part-film distance, the less the distortion (less magnification of the true size).

Focal-film distance—the greater the focal-film distance, the less the distortion (less magnification of the true size).

Tube alignment—improper alignment of the tube with respect to the part and film under consideration will result in variations in the part-film distances concerned with various portions in any plane and therefore result in unsymmetrical image representation.

Focal-spot size—the smaller the focal spot, the less the distortion (less magnification of the true size).

SECTION II. EXPOSURE FACTORS

131. GENERAL. Frequently, there arises the necessity to change the established exposure factors recommended for a given technique. The intensity of radiation varies inversely as the square of the focal-film distance. (See fig. 84.) Since density is affected by milliamperage, time, kilovoltage, and the distance, it is important to understand the mathematical rules which will govern their variation and control. It may be desired to increase or decrease the kilovoltage. Circumstances may require the use or removal of certain auxiliary devices such as diaphragms, cones, or grids. Intensifying screens may be desirable other than direct exposure with cardboard holders. In all of the foregoing situations, knowledge of the adequate compensations in the technique is essential.

132. MILLIAMPERAGE-DISTANCE RELATIONSHIP. The milliamperage (ma) requirements are directly proportional to the square of the focal-film distance (*d*). This relationship may be expressed in the following formula:

$$Ma_1 : Ma_2 : : D_1^2 : D_2^2$$

Where Ma_1 and D_1^2 are the original milliamperage and distance, respectively and conversely, and Ma_2 and D_2^2 are the new milliamperage and distance. conditions may arise where it is desired to change the milliamperage. It may be desired to increase the milliamperage to provide for shorter exposure time in order to minimize the effects of motion or the capacity of the tube may require a reduction in milliamperage. On the other hand, the quality of the roentgenogram might be increased by sharpness of the detail. This may be accomplished by an increase in the focal-film distance. Any change in the milliamperage or distance will affect the film density and, if one factor is changed, the other must be appropriately compensated. For an example, suppose the technique recommends for a P-A view of a skull, 76 kvp, 20 *ma*, 3¼ sec at 30-inch focal-film distance (D_1). If it is desired to increase the sharpness of the detail the distance may be increased to

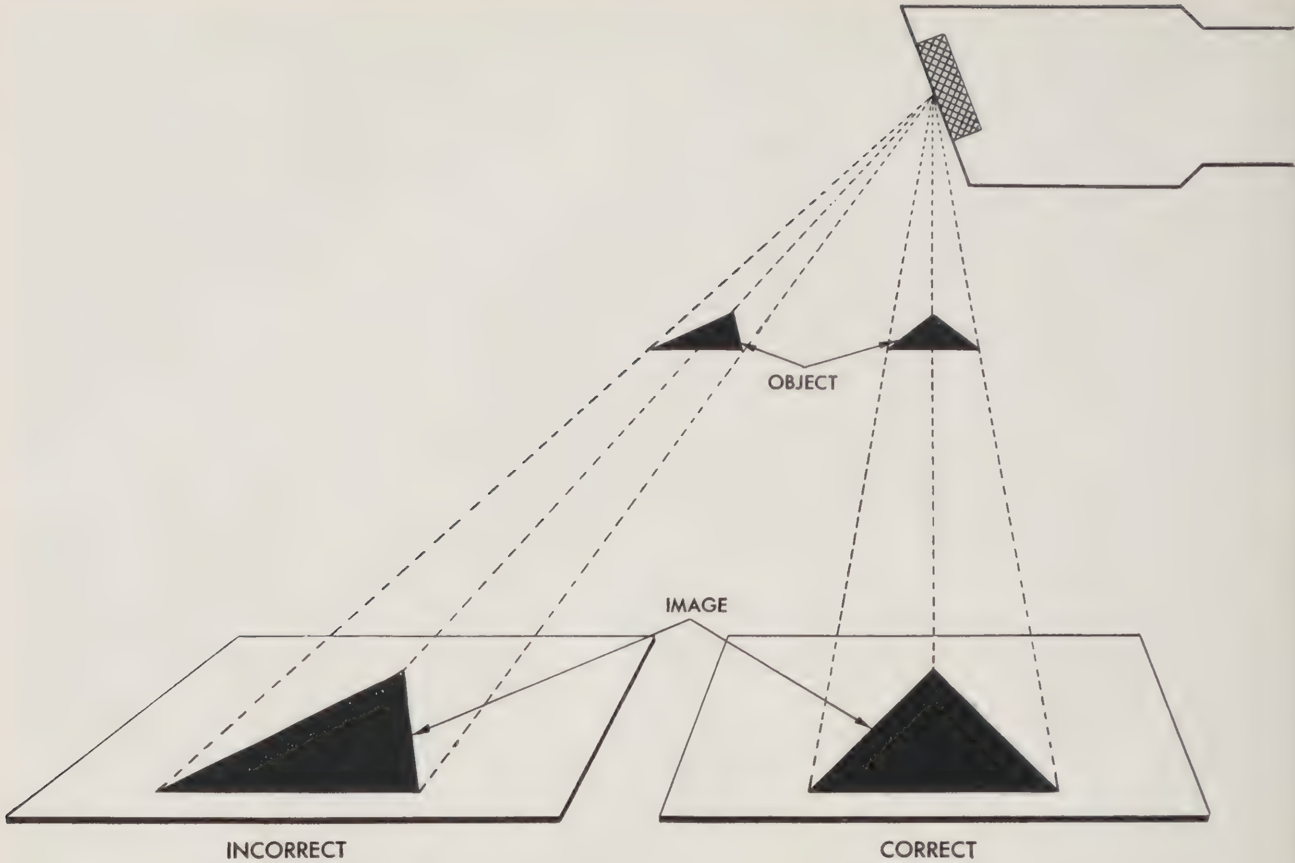


Figure 83. Distortion—result of poor alignment.

60 inches (D_2). By applying the formula, all other factors being constant, the new milliamperage (Ma_2) is obtained.

$$20:X::30^2:\ 60^2$$
$$20:X::900:3600$$
$$900X = 72{,}000$$
$$X = 80 \text{ milliamperes}$$

If it is desired to dispense with these simple calculations, table X, app. V may be consulted.

133. MILLIAMPERAGE-TIME RELATIONSHIP. The milliamperage (*ma*) requirements are inversely proportional to the time of exposure (S). This relationship may be expressed by the following formula:

$$Ma_1:Ma_2::S_2:S_1$$

If the previous example is utilized requiring 80 *ma* and assuming the capacity of the tube cannot be increased beyond 20 *ma* then the required film density at 60-inch focal-film distance can be obtained by increasing the original exposure time. By applying the formula, all other factors being constant, the new exposure time may be obtained.

$$80:20::X:3.25$$
$$20X = 260$$
$$X = 13 \text{ seconds}$$

In the above problem the total milliampere-seconds required for the exposure will be expressed in accordance with the formula:

$$Ma.S = Ma \text{ x } S \text{ (time in seconds)}$$

Therefore, if the milliamperage is changed, the time must be changed.

$$260\ Ma.S = 80\ Ma \text{ x } 3.25 \text{ seconds, or}$$
$$260\ Ma.S = 20\ Ma \text{ x } 13 \text{ seconds}$$

This last formula has wide usage in X-ray technique for the exposures are frequently expressed in *Ma.S* values. Additional examples follow:

$$10\ Ma.S = 200\ Ma \text{ x } 1/20 \text{ second}$$
$$10\ Ma.S = 100\ Ma \text{ x } 1/10 \text{ second}$$
$$10\ Ma.S = 10\ Ma \text{ x } 1 \text{ second}$$
$$52.5\ Ma.S = 30\ Ma \text{ x } 1\tfrac{3}{4} \text{ seconds}$$
$$65\ Ma.S = 20\ Ma \text{ x } 3\tfrac{1}{4} \text{ seconds}$$

134. TIME-DISTANCE RELATIONSHIPS. Exposure time (S) requirements are directly proportional to the square of the focal-film distance (D). This relationship may be expressed by the formula:

$$S_1:S_2::D_1^2:D_2^2$$

As in the above example, where a change in distance from 30 to 60 inches was made the required increase of the original exposure time (3.25 seconds) to the new exposure time can be obtained by applying the

formula:

$$3.25:X::30^2:\ 60^2$$
$$3.25:X::900:3600$$
$$900X = 11{,}700$$
$$X = 13 \text{ seconds}$$

The above solution is an alternative to the method described in paragraph 133.

135. MILLIAMPERAGE-TIME AND DISTANCE RELATIONSHIP. The milliamperage and time of exposure required for a given density are both directly proportional to the square of the focal-film distance. Since milliamperage and time may be expressed as *Ma.S* (par. 133) the following formula is derived:

$$Ma.S_1:Ma.S_2::D_1^2:D_2^2$$

136. KILOVOLTAGE-MILLIAMPERE-SECOND RELATIONSHIP. Any adjustments in kilovoltage which may be required, depending upon the technique, may be obtained from table XI, app. V. No definite mathematical relationship exists between kilovoltage, time, and milliamperage. The complex number of variables encountered in roentgenographic procedure permit only an approximation of correct values. To facilitate rapid application of these changes and to maintain uniform film density the following values will produce satisfactory results: a decrease of 10 kvp requires twice the original ma-sec; a decrease of 15 kvp requires an increase of four times the ma-sec; an increase of 10 kvp requires one-half the original ma-sec; an increase of 15 kvp requires one-fourth the ma-sec; a decrease of 28 kvp requires ten times the maS.

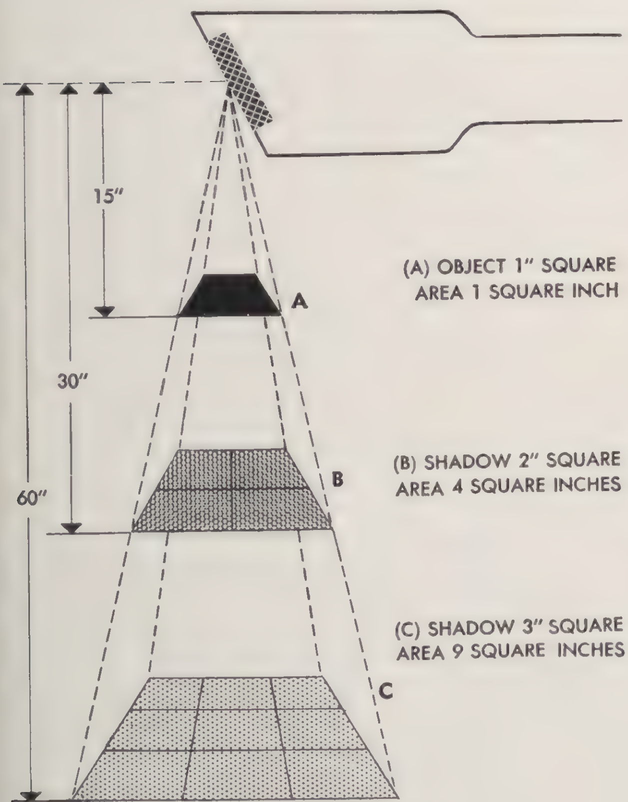


Figure 84. Inverse square law.

SECTION III. DEPARTMENTAL ACTIVITIES

137. GENERAL. In the United States Army, roentgenology is primarily a diagnostic service. With the exception of some of the general hospitals, the primary uses of the X-ray equipment available will be for roentgenography and roentgenoscopy. The attitude of the X-ray service should be one of constant readiness to aid all of the hospital services, medical, surgical, neuropsychiatric, and others. Because of its organization as a self-contained unit, certain responsibilities exist. These include care and protection of the patient, while he is in the radiological section; the initiating and maintaining of complete records, both film records and written reports; and, finally, the proper use of the equipment and materials allotted to the department, and the requisitioning of all equipment and materials which are needed for proper departmental function.

138. TREATMENT OF PATIENT. The roentgenographic and roentgenoscopic services differ from other laboratory services in the degree of contact between patients and technicians and the gravity of the technician's responsibility for the physical and mental welfare of the patient. The technician must realize that he is dealing with ill and injured people. He must consider in the handling of these patients that they have suffered great physical or mental stress. A pleasant, soothing manner of speech, with a professional, businesslike approach to the work at hand, always instills confidence. A cheerful greeting and a brief word of explanation costs nothing but induces the patient's cooperation. A calm and unaffected disposition promotes friendly relationships with patients, doctors, and the personnel of other departments. The physical comfort of the patient is also important. Adequate help to move patients to and from the stretchers and examination table is imperative. Stretcher patients should be moved to and from the X-ray department without delay. The technician should instruct the patient about the examination. For example, before roentgenography of the chest, patients should be told when and how to breathe. Ill or aged patients should be kept well covered on cold days; pillows should be adjusted for maximum comfort. Unusual conditions of patients, such as fainting, hemorrhage, or convulsion, should be reported immediately to the roentgenologist. Delirious and unconscious patients

should not be left alone, particularly when they are transferred on litters. An attendant nurse, or some responsible individual should be at their side at all times.

139. RELATIONSHIP TO ROENTGENOLOGIST. The technician is the first assistant of the roentgenologist. They work as a team, with mutual respect and sympathetic understanding of each other's professional responsibilities. The roentgenologist establishes departmental policies and routine regulations; it is the technician's duty to comply with them in both spirit and action. Cleanliness and orderliness of the department are responsibilities of the technician. These require interest and enthusiasm for one's work beyond the mere fulfillment of technical tasks.

140. MEDICAL ETHICS PERTAINING TO TECHNICIANS. The department of roentgenology is the crossroad of the hospital, for it is here that the many services meet and the conditions of many patients are discussed. The technician must not discuss nor disclose information about patients. He must not violate in any way the position of trust in which he finds himself. A genuine desire to help medical officers from other services to obtain films and reports of their respective cases must be displayed at all times. At no time, and under no circumstances, may he offer opinions, diagnoses or other information unless authorized in specific cases to do so. "Don't permit patients to see their films nor examination reports; don't talk about their diagnosis or what was seen at the roentgenoscopic examination; don't discuss any aspect of a case where the conversation might be heard by the patient." These are important "don'ts"; the technician must abide by them faithfully. Only by permission of the roentgenologist or the referring doctor shall the technician act otherwise.

141. SCHEDULES. In most X-ray departments the work for each week is scheduled with certain types of cases at certain hours. Thus, for example, gastrointestinal examinations might be scheduled on Monday, Wednesday, and Friday, while barium enemas may be performed on Tuesday, Thursday, and Saturday. Roentgenoscopic examinations may be done in the mornings; general roentgenographic examinations in the afternoons. Whatever the schedules may be, it is the duty of the technician to see that they are followed. The technician, who will let all of the nurses, wards, and clinics know about these schedules and also let them know how patients are to be prepared for various types of examinations, will save his superior much time and labor. A weekly check and clean-up schedule for equipment should be followed. Roentgen ray machines should be checked for visible defects. Exposed insulators should be cleaned and oil levels checked. Processing tanks and other darkroom fixtures should be cleaned. If the bulk of work runs uniformly from week to week, the preparation of new processing chemicals can be scheduled for a particular time. At the end of each day, an inspection should be made of all switches, lights, etc. Each machine should be tested to determine if it is in good working order for the following day.

142. RECORDS. The record system of X-ray departments are in general alike. There may be differences in minor details and the extent of the technician's participation in keeping of records may vary from department to department. Regardless of what system may be in effect, it is the technician's duty to familiarize himself with it. There is always the possibility that the file clerk or department secretary may be absent and that the technician would have to take over a portion of their duties temporarily. A request slip is the beginning of the patient's record. This comes to the X-ray department, usually before the patient. On it is the information pertaining to the patient, such as name, age, date, and description of the examination desired. Other pertinent data is also included. The technician should read these request slips carefully and completely. The information on them is his guide on how to handle the patient and to what roentgenography the patient is to be subjected. Upon arrival of the request slip, and in compliance with adopted schedules, the patient should be called to the department sufficiently early to check certain information. Patients should be asked to spell their complete names and corrections should be made on the request slip, when errors have occurred. Inquiry should be made as to previous X-ray examinations, either in the department or elsewhere. If the patient has been examined previously in the department, his record is obtained from the "old patients" file and his old X-ray number is written on his new request slip. The old X-ray diagnostic report is attached to the new request. Name, number, date, and examination data are then recorded on the daily report sheet. If the patient has not been X-rayed previously in the department, a name card is made up and his X-ray number is recorded on it. This card is filed alphabetically in the "old patients" file. In the future, the patient can be given the same X-ray number, if he should return for further examinations. After films of the patient are completed, the patient's old films, old diagnosis, new request, and new films are placed in the roentgenologist's office for interpretation. Following interpretation and the typing of the reports, the carbon copies are filed by number in the "X-ray history" files of the department. The original copy of the reports are sent to the ward or clinic from which the patient came. Films are placed in envelope preservers, with the patient's name and number written on the outside,

and filed according to number in the department's film file. The number of people outside of the department having access to films should be limited to a minimum. Films taken from the department should be signed for by the person taking them. Number of films, date, and the plate to which the films are taken should be included. Records of data for the operation of all X-ray machines and the general regulations and rules of procedure should be posted on bulletin boards in the machine booths. This information should be explicit, so that in case of the regular technician's absence, his substitute would have no difficulty in following the instructions. Records of films, number and sizes, should be kept daily. Records should also be kept of the number of chest films, G. I. films, bones and joints, etc. Life of X-ray tubes, valve tubes, and other deteriorating parts of X-ray equipment should be recorded. The technician should know his equipment, what it has done in the past, and what can be expected of it in the future.

SECTION IV. ROENTGENOGRAPHIC PROCEDURE

143. GENERAL. Before the X-ray technician attempts to accomplish the required exposures, he must have a comprehensive understanding of all the technical factors involved in roentgenography in order to produce roentgenograms of high quality. He must be able to utilize to the fullest advantage with expediency and economy all of the equipment and accessories available for his assignment.

144. PREPARATION FOR ROENTGENOGRAPHY. a. Film size. Wastage of film should be avoided. Size of film used will, of course, depend upon the area being roentgenographed. Besides the actual site of pathology a reasonable expanse of surrounding soft tissue should be visualized. Two or more views might be accommodated on one film by protecting certain portions of the film with lead masks while making one or another exposure.

b. Film container. A cardboard holder or a cassette may be employed. The use of a cardboard holder is recommended when the total thickness of the part to be roentgenographed measures 10 cm or less and when the maximum of detail is desired. Cardboard holders are recommended when a long scale of contrast in the gradation of the densities is indicated. They provide for a wide latitude of acceptable exposures. When fast exposures become necessary (that is, to overcome motion), or where the total part thickness to be roentgenographed measures more than 10 cm, casettes with intensifying screens are recommended. Furthermore, they are recommended when the utmost of contrast is desirable; for instance, to visualize early lesions contained within bone.

c. Positions. At least two positions (generally, an A-P or P-A and a lateral view) are ordinarily indicated. Stereoscopic projections, oblique or semilateral views should be considered. Elaborate procedures such as planigraphy, serialoscopy, kymography, encephalography, myelography, etc., are ordinarily special studies, either specifically requested or accomplished at a reexamination. (See ch. 11.) Particularly, when concerned with infants and children, it is advisable to include studies of the part of the opposite side as well as that of the part requested.

d. Stereoscopic projections. When this procedure is requested, stereoscopic pairs of films are made of any part of the body, but they are of particular advantage when two views of the same part (that is, A-P and lateral) cannot be made at right angles to each other. (See par. 254.)

e. Cone, diaphragm or grid. Cones are most frequently used in sinus, gall-bladder, and mastoid roentgenography. If a cone is not available a diaphragm should be used. (See par. 107.) ~~In general,~~ use of a grid (either stationary or of the Potter-Bucky type) is recommended for all exposures excepting the thinner parts of the extremities. One should not hesitate to use a cone or diaphragm, in addition to the grid, wherever possible. For instance, the combination of a cone and a grid may be necessary to adequately visualize a lumbosacral articulation in the lateral projection.

f. Captioning. Captioning of the film should include proper identification of the patient (by name or number) date of roentgenographic examination, name of hospital or clinic and orientation of side (right or left) plus any additional pertinent data in a manner prescribed in MR 1-9. Most clinics use numerical systems of identification. Lead numbers and letters are furnished by the medical supply for this purpose. The following is suggested:

(Separate strip)	(Separate strip)
7 1 42 R.	2 1 4 8 5
(Date) (Side)	(Patient's No.)

These lead numbers and letters may be placed on the cardboard holder or cassette and held in place by means of adhesive tape or any other suitable method. The individual's identification tag may easily be used to caption the film.

g. Immobilization. Inasmuch as the greatest "enemy" of detail is motion, the importance of absolute immobilization of the part being roentgenographed cannot be overemphasized. Immobilization bands or sandbags should be used whenever and wherever possible. Care must be exercised in fracture cases to avoid aggravating a condition already serious. In such cases, as well as those of noncooperative

patients, rapid exposure technique should be used.

h. Final precautions. Any and all ray-opaque objects should be removed from the patient when these are in or near the site for study. Routinely such objects as hair pins, dentures, soldier's identification tags, silk or rayon underclothing, etc., should be removed. Dressings, casts, splints, and other appliances are often left in position during roentgenography. Ray-opacity of these appliances will depend upon their composition and thickness. Ordinary cotton dressings do not affect the appearance of the roentgenogram materially but if dressings contain ointments or other medication having heavy metallic constituents, they become ray-opaque in corresponding degree. Dry plaster casts do not require much greater intensity of radiation; doubling the ma-sec. over ordinary technique usually being sufficient. Wet casts, however, are much more dense and usually three times the ma-sec. is needed, depending on the thickness of the cast. Many positions used in roentgenography are uncomfortable and occasionally painful. The table employed is likewise often uncomfortable. The roentgenogram should be made as quickly as possible after the patient is positioned correctly. Therefore, select the technique to be used, adjust the roentgenographic unit, identify films properly and have everything possible accomplished before the patient is positioned. This eliminates the necessity of having to position him a second time and will improve the standard of roentgenography. It is well to develop a routine for each type of examination, so that none of the necessary steps, such as identifying films, attaching or removing cone, etc., will be overlooked.

CHAPTER 9

ROENTGEN ANATOMY

SECTION I. INTRODUCTION

145. GENERAL. a. Basically, all things as they exist in nature are classified into three general groups: animal, vegetable, and mineral. The *mineral* objects are characterized as inorganic. They contain inorganic matter and are nonliving. The *animal* and *vegetable* groups are referred to as organic since they are composed of organic matter and possess life.

(1) An organism is defined as any living thing, plant, or animal. The fundamental difference between plants and animals is distinguished by the process of life each follows. Plants are capable, in most instances, of producing their own food. By a process called *photosynthesis* (action of sunlight causing the formation of carbohydrates from carbon dioxide in the tissues of the plants in the presence of a green substance called chlorophyl) plants remain fixed in one location. Animals, lacking the mechanism for the production of food, must seek food in order to live.

(2) Animals are classified according to the organization and characteristics of their structure. They are divided into the *invertebrates* (lacking a backbone) and the *vertebrates* (with a backbone). Included as vertebrates, from the simplest to the more complicated, are: fishes, amphibians, reptiles, birds, and mammals. The highest class of vertebrates is the mammal. Man is an example of a mammal. This class is subdivided into the order of primates including in order of evolutional development: lemurs, tarsioids, monkeys, baboons, gibbons, orang-utan, chimpanzee, gorilla, and man. Man (homo sapiens) is composed of many races; these being classified on the basis of skull and body measurements as well as superficial characteristics.

(3) Commonly, man is spoken of as a "human being" for it is in him that specialization and differentiation of function has attained its highest degree. Man is the only animal capable of speech and the ability to reason and integrate intelligently the many complex problems which confront him. It is in man that the nervous system has reached a high state of development which allows him to engage in complicated mental activities.

b. The human body is composed of various types of tissue and organs coordinated into a complex mechanism supported by a bony framework. The basic knowledge of the human body is essentially the result of many painstaking contributions from various allied scientific fields. The science dealing with the structure of the human body and the relation of its parts is human *anatomy*. This knowledge is based upon countless dissections of human bodies. The subject of anatomy is divided into the study of systems such as: *osteology*, the study of the bones or skeleton; *arthrology*, the study of the joints or articulations; *myology*, the study of muscles; *angiology*, the study of the blood-vascular system comprising the heart, blood vessels and lymphatic system; *neurology*, the study of the nervous system and the organs of special sense; and *splanchnology*, the study of *visceral anatomy*, including the respiratory, the digestive and urogenital system.

c. Embryology treats of the origin and development of the structures of the human body. It is concerned with the investigation of the minute and intricate formulation of the body cells, tissues, and organs.

d. Histology is a science which deals with studies of minute portions of the component parts of the human body and the composition of tissues—as provided with the use of a microscope.

e. Physiology is the study of the functions and activity of the various anatomical structures of the body. Primarily, it assists in formulating a clearer understanding of the reactions that take place within the body under certain conditions and enables the body to function as an integrated organism relative to chemical, physical, and mechanical stimuli.

f. Pathology is a science which deals with variations in the structure and functions of the body as caused by disease.

146. ANATOMICAL TERMS. a. For descriptive purposes, the body is considered to be in the erect position when the arms are hanging by the sides and the palms of the hands are directed forward. This is referred to as the normal anatomical position. (See fig. 85.)

(1) Anterior is the front or ventral part of the body.

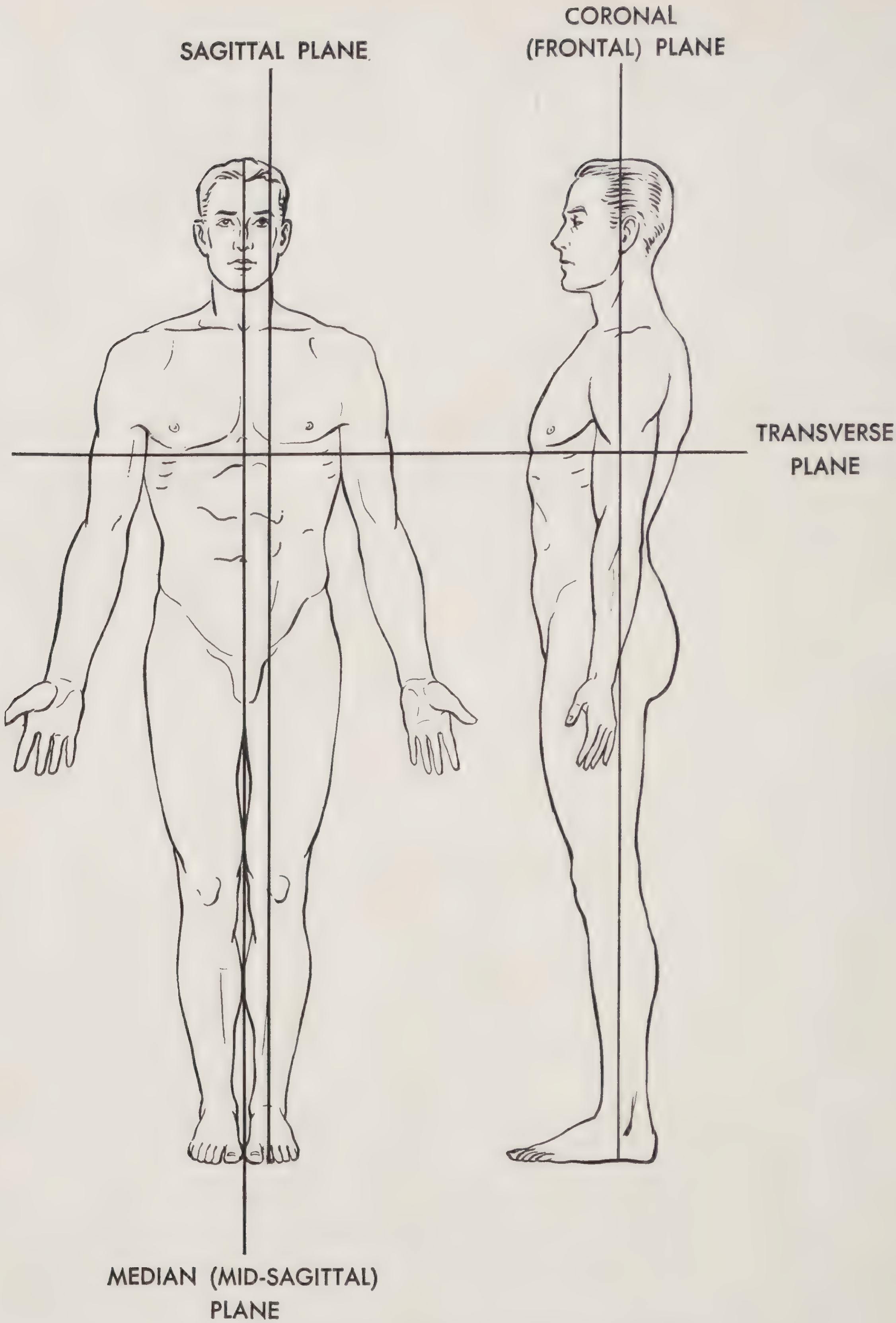


Figure 85. Anatomical planes—anterior and lateral views.

(2) Posterior is the back or dorsal part of the body.

(3) Medial pertains to nearness to the midline (midsagittal plane).

(4) Lateral pertains to a relationship of distance from the midline.

(5) Internal means situated or occurring within or on the inside—particularly with respect to a hollow viscus or cavity.

(6) External means the opposite of internal.

(7) Proximal means nearness to a point under comparison.

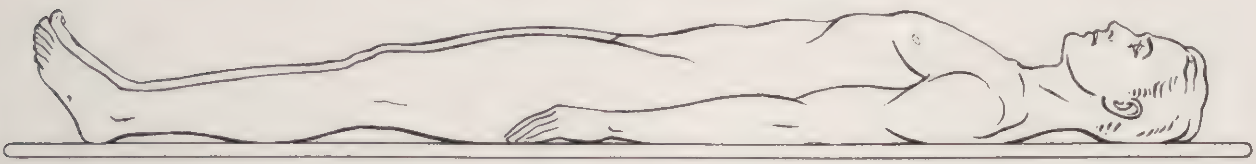
(8) Distal is the opposite to proximal.

(9) Superior refers to a point, part or region which is higher, directed above or "cephalad."

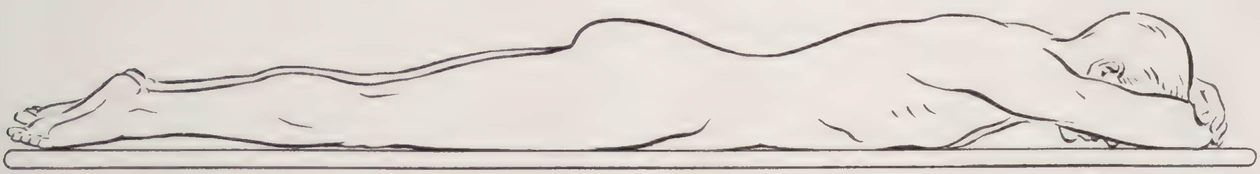
(10) Inferior is the opposite of superior. Rather than cephalad it refers to a "caudal" relationship.

b. In X-ray activities such terms as anteroposterior, posteroanterior, inferolateral, etc., are frequently used. In the case of *anteroposterior,* the prefix *antero* indicates that the principal ray enters the anterior aspect of the body whereas the suffix posterior indicates the principal ray emerges from the posterior aspect. In other words, the anterior portion of the body faces the X-ray tube while the posterior portion is closer to the X-ray film. Many combinations of the foregoing anatomical terms may be employed in this manner to indicate the aspect of the body through which the principal ray enters and emerges.

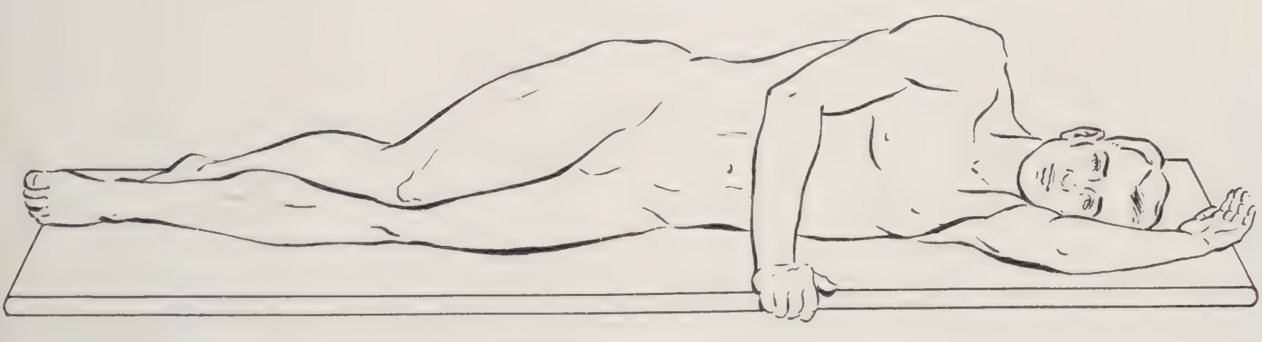
147. ANATOMICAL PLANES. a. Median plane, often called the midsagittal plane, is an imaginary plane passing in a vertical anteroposterior direction which extends through the midline of the trunk



SUPINE



PRONE



LATERALLY RECUMBENT

Figure 86. Anatomical postures.

dividing the body into two, exactly symmetrical parts. Thus, there can be only one median plane.

b. Sagittal plane is an imaginary plane which is parallel to the median plane. Hence, the body may be divided into many sagittal planes, each passing in a vertical anteroposterior relationship.

c. Coronal, or frontal plane, is any imaginary vertical plane which passes at right angles to the median plane.

d. Transverse plane is any plane which passes in a horizontal direction at right angles to both the coronal and median planes. It would divide the body into cross sections.

148. ANATOMICAL POSTURES. a. Supine—a horizontal position of the body lying flat on the back. (See fig. 86.)

b. Prone—a horizontal position of the body lying face and trunk down. (See fig. 86.)

c. Laterally recumbent—the horizontal position of the body lying on either the right or left side. (See fig. 86.)

d. Erect—the normal posture of the body in either a sitting or standing position.

SECTION II. ORGANIZATION OF THE HUMAN BODY

149. GENERAL. The human body is composed of the head and neck, thorax and abdomen, and the extremities, both upper and lower. Due to the high degree of differentiation and specialization, the body is composed of countless numbers of *cells*. These cells are arranged into *tissues*. Each type of tissue performs intricate physiological reactions. The organization of tissues to execute specific physiological functions is known as an *organ*. The coordination of all the various organs in the performance of a unified function is known as a "system."

150. THE CELL. a. All cells, tissues, and organs of the body are developed as a result of the fertilization of the egg or *ovum* (female germ cell) by the *spermatozoon* or sperm (male germ cell). Each is a product of the *gonads* (sex glands). The fertilized germ cell (zygote) divides into an enormous number of cells which become greatly modified by size, shape, and function depending upon their location within the body and upon the chemical, physical, and mechanical phenomena which they must integrate.

b. The cell, as constituted, is composed of *protoplasm*. The cell substance is a viscid, translucent, jellylike material composed mainly of proteins, fats, carbohydrates, and inorganic salts. Within the cell is found a small spherical body called the "nucleus." The small irregular masses within the nucleus which take part in reproduction are *chromosomes*.

151. FUNCTION OF LIVING CELL. In order for a single cell to carry on all the processes necessary for life it must be capable of the following:

a. Irritability—the property of responding to stimulation received from its surroundings.

b. Conductivity—the ability to conduct stimulation within itself and to other cells. Nerve cells are highly specialized for this function.

c. Contractility—the ability to react to stimulation by way of motion. This property reaches its highest degree of specialization in muscle cells.

d. Metabolism—the inherent property of all cells to take in certain energy materials and build them up into cell substance; then, to remove the waste materials resulting from the cellular activities. The building-up phase is called "anabolism"; the breaking-down phase is "catabolism." The cells of the digestive tract are specialized for the complex processes of anabolism.

e. Reproduction—the property of developing new cells.

152. REPRODUCTION OF THE INDIVIDUAL. The development of a new individual organism or human being is provided by the sex cells (ova of the female and spermatozoa of the male). The female germ cells leave the ovary at regular intervals and enters the genital tract. The ova are nonmotile and they always are large in comparison to the spermatozoa. The spermatozoa are extremely small and are very active. The union of the female germ cell with the male germ cell results in the formation of a new animal, namely, the "zygote" or fertilized egg. During the entire period of growth within the mother, which is about 9 months, the developing organism is in a fluid medium called the "amniotic fluid" and is surrounded by the *maternal* and *fetal membranes*. The exchange of materials is accomplished by means of the *umbilical cord*.

153. PERIODS OF HUMAN DEVELOPMENT. Human life is divided into several stages. It commences with the act of fertilization and terminates with death. The period prior to birth is described as "prenatal"; that following birth, "postnatal." The development of the individual might be considered as follows:

a. Ovum period—begins at fertilization and terminates at the end of the second week of prenatal life.

b. Embryonic period—extends from the end of the second week to the end of the second month.

c. Fetal period—the end of the second month to the time of birth.

d. Newborn or neonatal period—birth to the end of the second week of postnatal life.

e. Infancy—end of second week until time when the infant assumes an erect position. This varies

from the end of the first year to the thirteenth month.

f. Childhood—end of the first year until about the thirteenth year in females and about the sixteenth year in males. *Puberty* marks the end of childhood.

g. Adolescence—puberty to the late teens in females and to the early twenties in males.

h. Maturity—the end of the adolescent period to senility or old age.

154. CONCEPT OF BIOLOGICAL INHERITANCE. In accordance with modern knowledge, structural, and functional characteristics of each species, race and family are inherited through chromosomes which are found in the nuclei of the cells. At the time of fertilization an equal number of chromosomes are contributed by the female germ cell and the male germ cell so that the fertilized cell has an equal amount from each. The chromosomes carry *genes* which are the factors by which the transmission of inherited characteristics is accomplished. A considerable number of racial, family, and individual differences are known to be inherited, but the mechanism by which this is accomplished is not exactly known. Body size and form, for an example, have a genetic basis. Head and face, color of eyes, skin, and hair are other inherited characteristics.

155. BODY TYPES. Considerable variation of form and position is exhibited by the organs of the same subject depending upon the posture and other conditions. There is also a difference of general body form and associated structures among various individuals. The normal type of individual is referred to as "sthenic." A short, broad stocky type is known as "hypersthenic." The slender individual with a long narrow trunk is called "hyposthenic."

156. REGIONS OF BODY. For the purposes of description, the abdomen is divided into nine regions by means of two horizontal and two vertical lines. (See fig. 87.) The upper horizontal line passes through the tenth costal cartilage inferiorly. The lower line passes through the level of the anterior superior iliac spines. Each vertical line passes through a point midway the length of the inguinal ligament. The regions above the upper horizontal line are the right and left hypochondriac and the epigastric. Between the horizontal lines are located the right and left lumbar and umbilical. Below the lower horizontal line are located the right and left iliac and hypogastric regions.

157. FUNDAMENTAL TISSUES OF THE BODY. a. The cells in the different tissues of a highly developed individual are grouped into five general classes: epithelial, connective, muscle, blood, and nervous.

b. Epithelial. These cells form the covering of the body, the secreting portion of glands, the channel of various ducts and tubes, and the lining of the circulatory and digestive tracts.

c. Connective tissue serves as a binding and supporting element. It includes ligaments, tendons, cartilage, bones, and the supporting cells of all organs.

(1) Ligaments—strong flexible bands of connective tissue which usually serve to bind together bones that enter into the formation of joints.

(2) Tendons—dense white cords of connective tissue usually tubular in shape and of varying thickness. They serve to fasten muscles to bones. Flattened tendons consisting of thin, flat sheets of connective tissues are called "aponeuroses." They serve to connect one muscle with another or with the periosteum of bone.

(3) Cartilage—sometimes referred to as gristle is a smooth, firm and tough layer of cells frequently located at the ends of bone in joint formations. It is covered and nourished by a tissue layer called the "perichondrium."

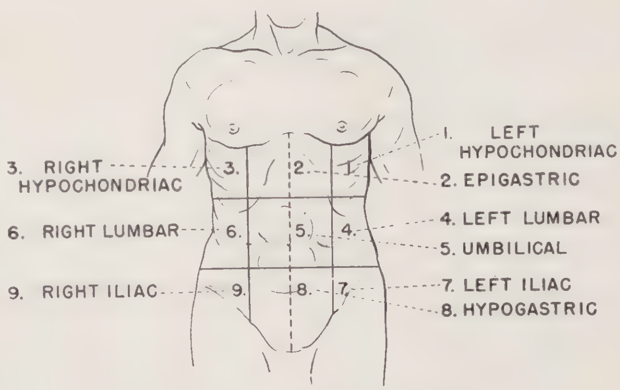


Figure 87. Regions of abdomen.

(4) Bone—a form of connective tissue in which the intercellular substance has been made extremely dense by the deposition of calcium and other mineral salts. The outer layer is hard and is known as "compact" while the inner spongy portion is called "cancellous." In long bones, there is present a *medullary cavity* containing red and yellow marrow. A thin vascular membrane covers the outer layer of bone and is called "periosteum." The main function of periosteum is regeneration of new bone in addition to nourishment of normal growing bone. The quantity of mineral salts present in bone determines the degree of opaqueness and hence the amount of unabsorbed X-rays that will sensitize the X-ray film. Since cartilage is usually less dense than bone, differentiation can be made between them. Consequently, the areas of high tissue density will be

recorded on the X-ray film as low roentgenographic densities.

d. Muscle cells possess to a high degree, the property of contractility. In addition, muscle cells have two other conspicuous properties—that of irritability and conduction of stimuli. The movements of the body are not directly produced by the contraction of the muscles, but through the intermediary action of bones acting as levers. There are three types of muscle cells:

(1) Smooth muscle—functions involuntarily, that is, the contractions are not under the control of the mind. It is described as smooth because it lacks striations within its structure. It is found mainly in the walls of the viscera, the urinary bladder, the gall bladder, fallopian tubes, and the blood vessels.

(2) Striated muscle—comprises the skeletal muscles of the body which function under control of the mind. This type is grouped as masses or bundles having definite names.

(3) Cardiac muscle—composed of cells which constitute the dynamic musculature of the heart. This type of musculature shows striations as found in voluntary muscles and to some extent resembles smooth muscle. It possesses within itself the power to initiate contractions of the heart muscle, but the rate is controlled by the nervous system.

e. Blood cells—are not fixed to one location. They are considered as tissue elements circulating within a fluid media known as "plasma." The average blood volume is about 8.8 percent of the body weight. The blood is composed of various types of cells:

(1) Red blood cells (erythrocytes) are shaped like a disk.

(2) White blood cells are colorless and extremely variable in shape and number. Several varieties of white blood cells are identified. With staining, the nucleus and other constituents show up very conspicuously.

(*a*) Lymphocytes resemble red cells in size but contain a large spherical nucleus.

(*b*) Transitional leucocytes are about the same size as large lymphocytes with a nucleus in the shape of a horseshoe.

(*c*) Mononuclear leucocytes resemble the large lymphocytes.

(*d*) Polymorphonuclear leucocytes have a nucleus, irregular in shape. Three varieties are classified on the basis of their staining reactions: *basophils*, *eosinophils*, and *neutrophils*.

(3) Platelets are minute round bodies found in the fluid medium of the blood. They appear as cell fragments. They do not contain nuclei.

f. Nerve cells—highly conductive cells such as found in the brain, spinal cord, peripheral nerves, ganglia, and plexuses.

SECTION III. ARTHROLOGY

158. GENERAL. **a.** Arthrology is the study of joints or articulations. There are three general types: *synarthrodial, amphiarthrodial,* and *diarthrodial.*

b. Synarthroses or the immovable type is that articulation in which the surfaces of each bone are separated by a thin layer of connective tissue or hyaline cartilage. The bones of the skull are separated by this type of joint which is referred to as a "suture." In many cases the intervening cartilage may be replaced by true bone and then there is developed a "synostosis."

c. Amphiarthroses—slightly movable joints where the articulations are covered with an articular cartilage and separated by a broad disk of fibrocartilage. This type may be exemplified by the joints between the spinal vertebrae.

d. Diarthroses are freely movable joints. They are composed of an articular cartilage connected by an articular capsule and ligaments to form a cavity between the articulating surfaces of the ends of the articulating bone. This type of joint might be further classified as follows:

(1) Hinge-joint—as exemplified by the elbow, knee, and ankle joints.

(2) Pivot-joint—such as found in the articulation of the odontoid process of the axis with the atlas in the cervical vertebrae.

(3) Ball and socket joint—such as the hip and shoulder joints.

(4) Gliding joints—such as found between the bones of the wrist.

159. TYPES OF JOINT MOVEMENT. **a.** Flexion—the act of bending one part of the body upon the other. For example, the bending of the forearm upon the arm, the leg against the thigh, or the fingers onto the palm of the hand.

b. Extension—the method by which a part of the body is placed in an outstretched or straightened condition.

c. Abduction—the movement of a part of the extremities away from the median plane of the body.

d. Adduction—the opposite of abduction and is therefore a movement of the part towards the median plane.

e. Rotation—involves the movement of a part around a central axis.

f. Pronation—movement of a part such as the palm of the hand or ventral aspect of the body in a downward position.

g. Supination—the act of turning the palm or body upwards.

h. Eversion—the movement of the part outward.

i. Inversion—the movement of a part inward.

SECTION IV. OSTEOLOGY

160. GENERAL. The essential framework of the body upon which all soft tissues, organs, vessels are dependent for support is the skeleton. It is composed of bones of various shapes supplemented by cartilage in certain regions. (See figs. 88 through 90.) There is an axial portion, including the bones of the neck, head and trunk, and, an appendicular portion including the bones of the extremities (upper and lower). The adult human skeleton consists of approximately 206 bones.

a. *Appendicular skeleton.*

(1) Upper extremities	64
(2) Lower extremities	62
	126

b. *Axial skeleton.*

(1) Skull	22
Auditory bones	6
Hyoid bone	1
(2) Vertebral column	26
(3) Ribs and sternum	25
	80
Total	206

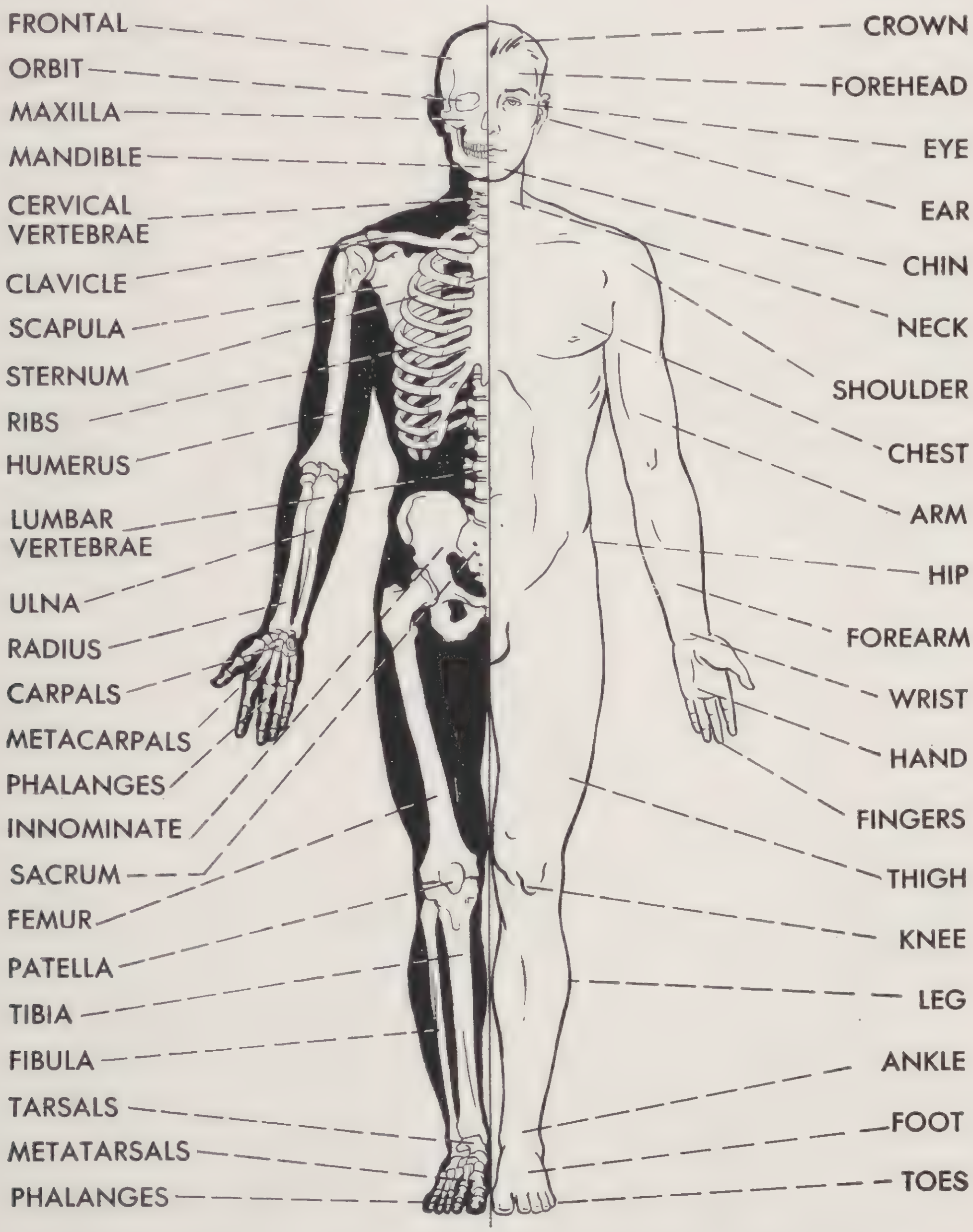


Figure 88. Relationship of soft tissues to the skeleton—anterior view.

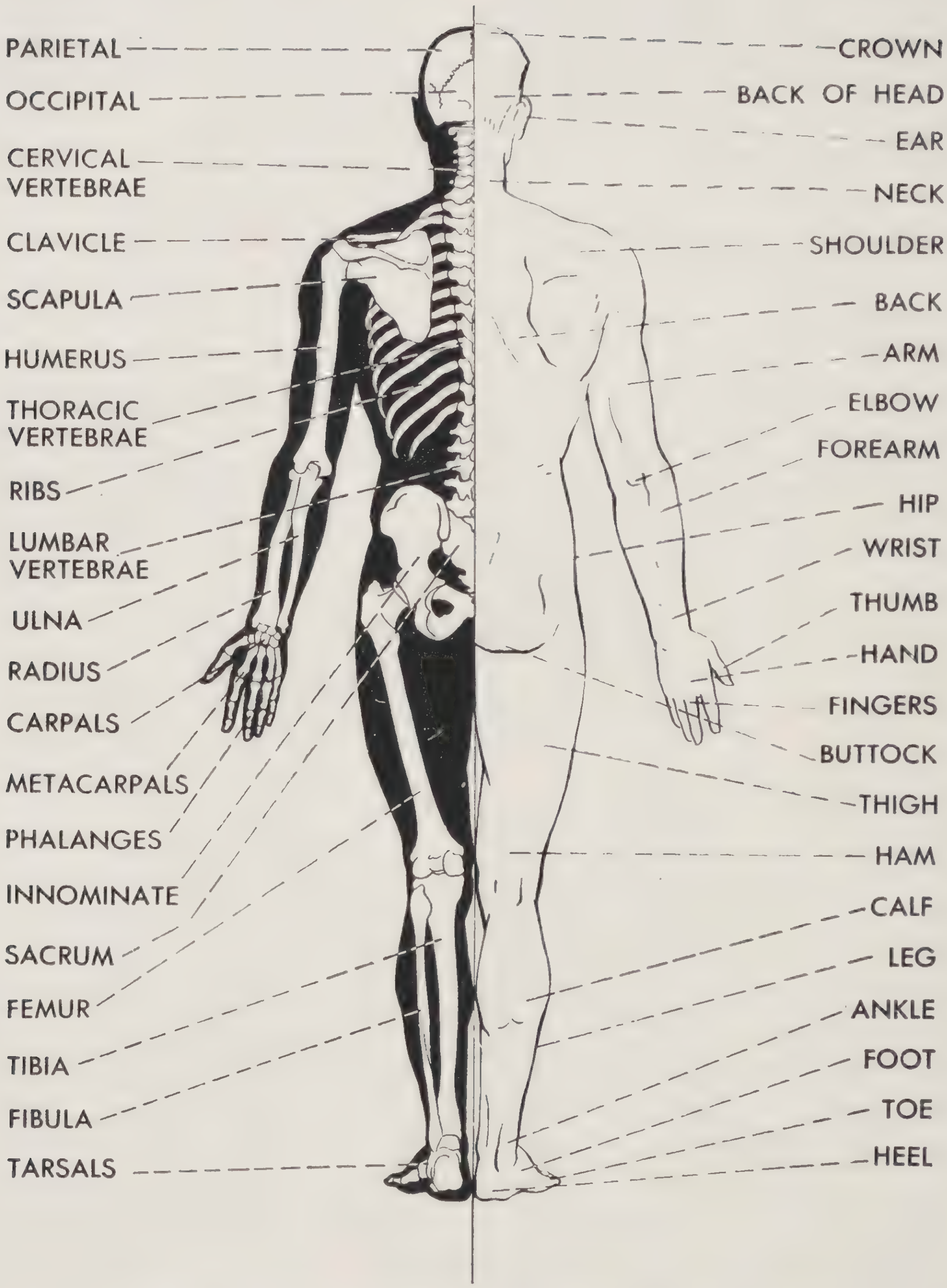


Figure 89. Relationship of soft tissues to the skeleton—posterior view.

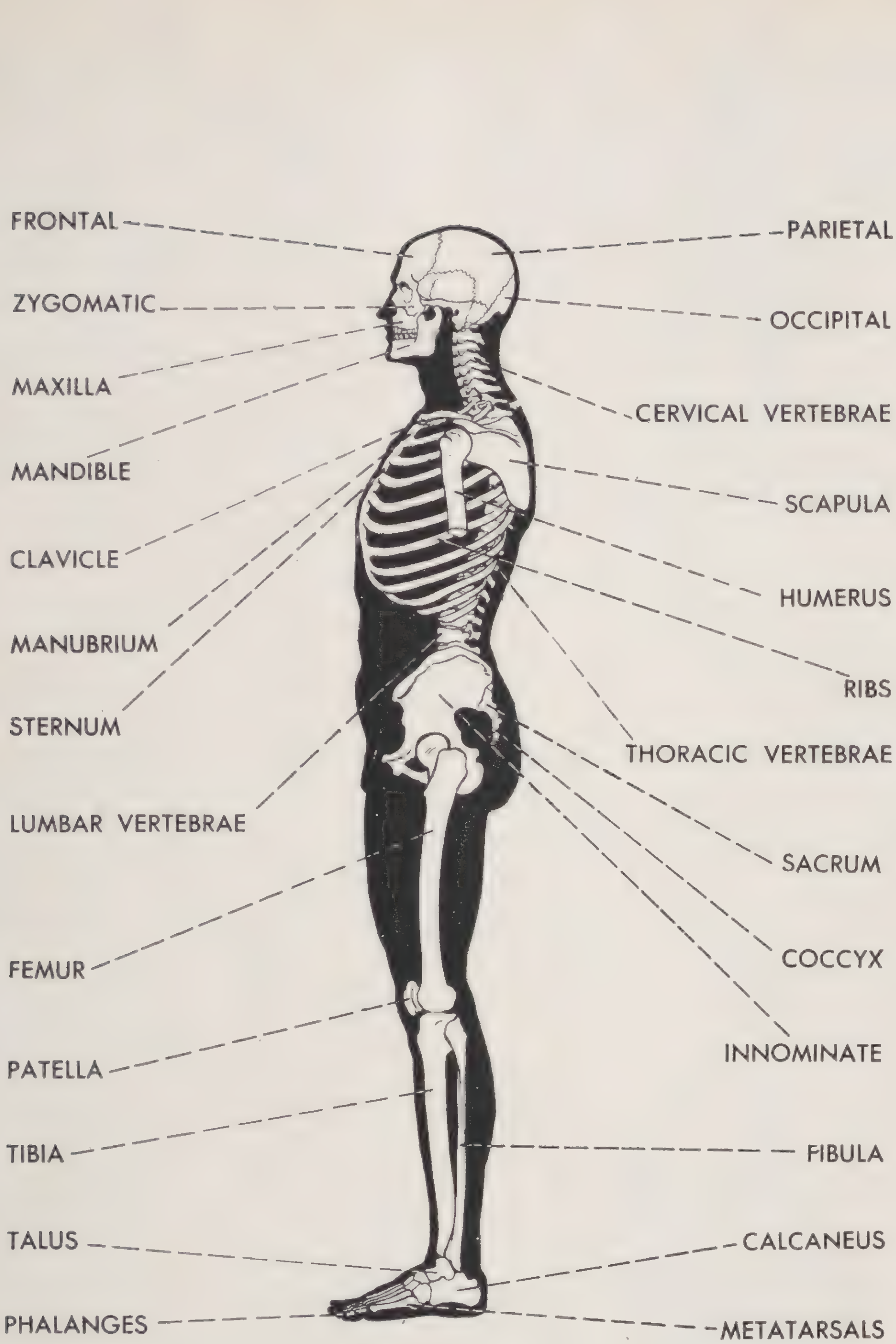


Figure 90. Relationship of soft tissues to the skeleton—lateral view.

161. CLASSIFICATION OF BONES.

a. There are four classes of bones: long, short, flat, and irregular.

b. Long bones are found in the limbs where they act as levers. They consist of a body or shaft and two ends or extremities. The body or shaft contains a central or *medullary cavity* and walls which are composed of compact bone. Spongy bone extends into the cavity and towards the ends.

c. Short bones are composed of a spongy bony substance surrounded by a thin crust of compact bone. They are located in those parts where strength and compactness are essential, as in the case of the metacarpals or phalanges.

d. Flat bones are composed of two thin layers of compact bone separated by a spongy substance. In the cranium the layers are known as the tables of the skull and the intervening substance as "diploe." In certain regions of the skull, absorption of bone occurs between the tables with the result that air spaces or *sinuses* are formed. In addition to the bones of the cranium, other examples of flat bones include the scapula, the ilium and the sternum.

e. Irregular bones include all the bones which lack a uniform shape. The vertebrae, carpals and tarsals are good examples.

162. DESCRIPTIVE TERMS OF BONE STRUCTURE.

Various parts of the bone may be described in the following terms:

a. Condyle—a rounded eminence at the articular (joint) end of a bone.

b. Crest—a projecting ridge.

c. Head—the expanded end particularly when situated beyond a constricted or neck portion.

d. Process—a distinct projection.

e. Spine—a sharp slender projection.

f. Tubercle—a small eminence or elevation.

g. Tuberosity—a relatively large elevation or eminence.

h. Foramen—a hole or perforation through which may pass such structures as nerves, arteries, and veins.

i. Fossa—a depression or hollow pit.

j. Groove—a shallow linear type of depression.

k. Fontanel—an unossified membranous portion in the cranium of an infant.

l. Meatus—a relatively large opening.

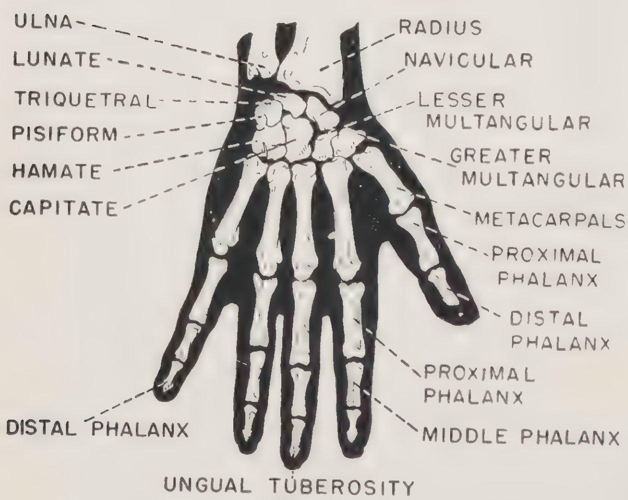


Figure 91. Bones of the hand and wrist.

163. UPPER EXTREMITY.

The upper extremity is composed of the hand, the forearm, arm and shoulder. Considering each of these parts, the bones of each upper extremity include the following:

a. Phalanges (fingers)	14
b. Metacarpals (palm of hand)	5
c. Carpals (wrist bones)	8
d. Radius (small bone of forearm)	1
e. Ulna (elbow bone of forearm)	1
f. Humerus (arm bone)	1
g. Clavicle (collar bone)	1
h. Scapula (shoulder bone)	1
	32

164. HAND.

It consists of two segments: the metacarpals and the phalanges. (See fig. 91.)

a. Metacarpal bones are five in number. They are identified by enumeration from the thumb side. Each of these bones has a *body*, a *base* or proximal end and a *head* or the distal end.

b. Phalanges are fourteen in number, three for each of the fingers, and two for the thumb. The thumb is considered to be the first finger; the index finger, the second, etc. Each *phalanx* has a body, a *distal* and a *proximal* end. The terminal part of each distal phalanx ends in the *ungual tuberosity* or *tuft.*

165. WRIST.

a. The carpal bones are eight in number and are arranged in two rows. Those of the proximal row from the thumb to the fifth finger side are named in the order as follows: navicular, lunate, triquetral, and pisiform bones; those of the distal row, in order, are: greater multangular, lesser multangular, capitate, and hamate. (See fig. 91.)

(1) The navicular (scaphoid) is the largest of the proximal group. Its name is derived from the fact that it resembles the outline of a boat. It is on the thumb side of the proximal row.

(2) The lunate (semilunar) is distinguished by its deep concavity and arch-shaped outline. It is situated in the middle of the proximal row, between the navicular and the triquetral.

(3) The triquetral (cuneiform) is characterized by its pyramidal or three-cornered shape. It is situated on the ulnar aspect of the proximal row.

(4) The pisiform is a pea-shaped bone situated in a tendon in front of the triquetral.

(5) The greater multangular (trapezium) as the name implies, is one of the largest of the carpals. Its shape is of many angles and it is situated on the thumb side of the distal row.

(6) The lesser multangular (trapezoid) is the smallest bone in the distal row. It is located just to the side of the greater multangular.

(7) The capitate (os magnum) is the largest of the carpal bones. It is located in the distal row between the lesser multangular and hamate.

(8) The hamate (unciform) may be distinguished by its wedge-shaped, hooklike process. It is located in the distal row superior to the fourth and fifth metacarpals.

b. Articulations of bones of hand and wrist. The phalanges articulate with the metacarpal bones. The latter articulate also with the carpal bones. The carpal bones also articulate with the radius and ulna.

166. FOREARM. a. It is that part of the upper extremity located between the wrist and the arm. It has two bones: the radius and the ulna. (See fig. 92.)

b. The radius is situated on the lateral side. It is a long, slightly curved bone having the following landmarks:

(1) Head—a cup-shaped disklike structure situated at the proximal end and adapted for articulation with the capitulum of the humerus (bone of arm, proper).

(2) Neck—the round, smooth constricted portion distal to the head.

(3) Radial tuberosity—located on the medial side of the neck.

(4) Body of shaft—the main portion, extending from the neck to the region of the styloid process.

(5) Styloid process—a downward, conical projection on the lateral side of the distal portion.

(6) Ulnar notch—a small depression on the medial side of the distal end of the radius.

c. The ulna is situated in the medial portion of the forearm and contributes prominently to the formation of the elbow. It is composed of the following structures:

(1) Olecranon process—a large, curved eminence on the proximal end.

(2) Coronoid process—a large, pyramidal projection from the anterior surface of the proximal portion.

(3) Semilunar notch—the arched depression extending between the olecranon and the coronoid processes.

(4) Radial notch—the oblong depression on the lateral side of the coronoid process.

(5) Styloid process—a conical projection of bone on the medial side.

d. Articulations of the forearm. The radius articulates with the humerus at the capitulum and the ulna, at the radial notch on the proximal end, and,

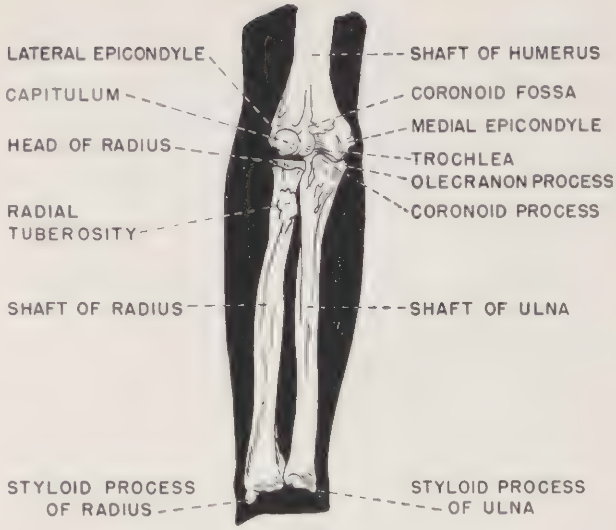


Figure 92. Forearm—anteroposterior view.

with the ulna at the ulnar notch and the lunate and navicular at the distal end. (See figs. 91 and 92.) Proximally, the ulna articulates with the humerus at the semilunar notch and with the radius at the radial notch and distally, with the radius at the ulnar notch. The *elbow joint* is the articulation of the radius and ulna with the humerus. It is classified as a diarthrodial—hinge joint. (See fig. 93.)

167. ARM. a. The arm proper has one bone, the humerus. (See fig. 93.) It is the longest and largest bone of the upper extremity. It is that portion which extends between the shoulder joint and the el-

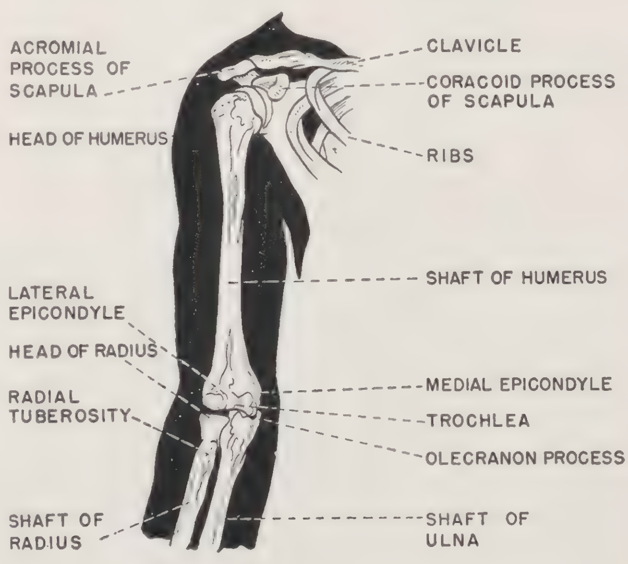


Figure 93. Articulations of the humerus—anterior view.

bow joint. It may be described by the following landmarks:

(1) Head—the rounded, proximal end.

(2) Anatomical neck—that portion which is located between the greater and lesser tuberosities and the head.

(3) Surgical neck—the constricted portion below the tuberosities. It is so named because it is frequently the site of fracture.

(4) Greater tuberosity—the larger eminence on the lateral side of the proximal end.

(5) Lesser tuberosity—the smaller eminence on the medial side of the proximal end.

(6) Intertubercular sulcus—a groove between the two tuberosities.

(7) Shaft or body—the main portion extending from the neck to the condyles.

(8) The musculospiral groove—a shallow, oblique impression on the upper half of the shaft. It serves as the pathway for the radial nerve.

(9) The lateral and medial epicondyles—projections on each side of the distal end.

(10) Capitulum—the smooth, rounded eminence on the lateral surface of the articular area at the distal end.

(11) Trochlea—the medial portion of the articular surface on the distal end.

(12) Radial fossa—a slight depression on the anterior aspect superior to the capitulum, for accommodating the head of the radius during flexion of the forearm.

(13) Olecranon fossa—a deep, triangular depression superior to the posterior aspect of the trochlea.

(14) Coronoid fossa—a depression superior to the anterior aspect of the trochlea, for accommodating the coronoid process of the ulna during flexion of the forearm.

b. Articulations of the humerus. The humerus articulates with the scapula at the proximal end and with the ulna and radius, at the distal end. The articulation with the scapula is a ball and socket type of a diarthrodial joint. (See fig. 93.)

168. SHOULDER BLADE. a. The scapula is the shoulder blade. It is a large, flat bone, roughly triangular in shape. It lies against the posterior aspect of the thorax and extends from the second to the eighth rib. (See fig. 94.) It may be described by the following landmarks:

(1) Subscapular fossa—the broad concavity on the costal (rib) aspect or anterior surface.

(2) Spine—a projecting plate of bone located on the posterior surface dividing the scapula into the supraspinous and infraspinous fossae.

(3) Supraspinous fossa—the smaller of the two fossae and it is located above the spine.

(4) Infraspinous fossa—the concavity situated below the spine.

(5) Acromion—a triangular projection extending anteriorly, at the lateral extremity of the spine.

(6) Coracoid process—a thick, curved process attached by a broad base to the upper part of the neck of the scapula.

(7) Glenoid fossa or glenoid cavity—the shallow concavity located at the lateral angle of the scapula. It contributes to the formation of the shoulder joint.

(8) Lateral angle—that portion of the scapula where the superior and axillary borders meet.

(9) Medial angle—that part of the scapula where the superior border meets the vertebral border.

(10) Inferior angle—the rounded extremity at the junction of the vertebral and axillary borders.

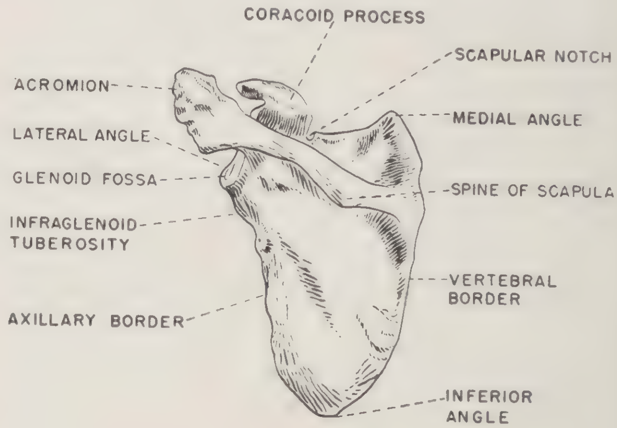


Figure 94. Scapula—posterior view.

b. Articulation of the scapula. The scapula articulates with the acromial extremity of the clavicle, at the acromion process, and with the head of the humerus at the glenoid fossa. (See fig. 93.)

169. COLLAR BONE. a. The clavicle, a long practically tubular bone, shaped somewhat like the italic letter "*f*." It may be described by the following landmarks:

(1) Sternal end—the medial portion.

(2) Acromial end—the lateral portion of the clavicle.

(3) Coracoid tuberosity—a rough eminence located on the posterior border of the lateral third of the bone.

(4) Costal (rib) tuberosity—a rough area located on the medial aspect of medial third.

b. Articulations of the collar bone. The sternal end of the clavicle articulates with the manubrium sterni while the acromial end articulates with the acromion of the scapula.

c. The clavicle and the scapula, together are described as the shoulder girdle.

170. LOWER EXTREMITY. Commonly, the lower extremity is called the leg. Anatomically, the leg is merely that part between the knee and the ankle. The part between the knee and the hip is referred to as the thigh, while below the ankle is the foot and the toes. The bones of each lower extremity include the following:

a. Phalanges (toes)	14
b. Metatarsals (sole and lower instep)	5
c. Tarsals (ankle)	7
d. Fibula (small bone of the calf)	1
e. Tibia (shin bone)	1
f. Patella (knee cap)	1
g. Femur (thigh bone)	1
h. Innominate (hip bone)	1
	31

171. PHALANGES. Commonly called the toes of the foot. They are similar in number and arrangement to those of the hand. Each is composed of a body, head, and base. The tip of the distal phalanges terminate as the *ungual tuberosities.* (See figs. 95 and 96.)

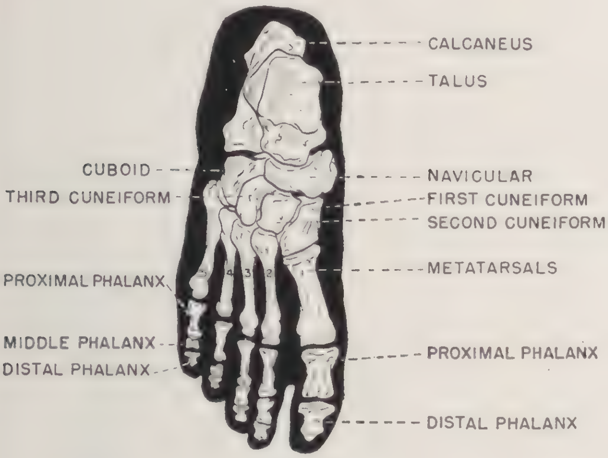


Figure 95. Bones of the foot—anterior view.

172. METATARSALS. They are the five bones forming the sole and lower instep of the foot and are numbered from the great toe side, laterally as 1st, 2d, 3d, 4th, and 5th. Each consists of a body, base, and head. Union of these bones by means of ligaments constitutes the *arch* of the foot.

173. ANKLE. a. The tarsal bones are seven in number and are referred to as the ankle bones. (See fig. 96.) They are described as follows:

(1) Talus (astragalus),—second largest of the tarsal bones. It supports the tibia and rests on the calcaneus.

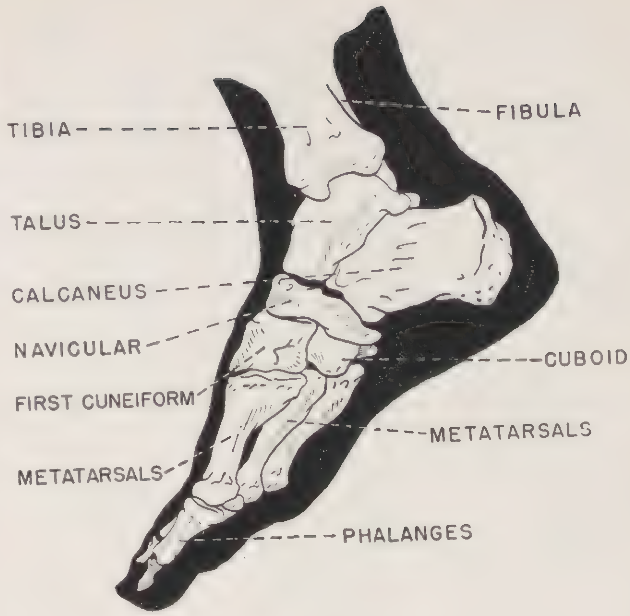


Figure 96. Bones of the foot—lateral view.

(2) Calcaneus (os calcis)—largest of the tarsal bones, is irregularly cuboidal in shape. It is situated beneath the astragalus and provides the shape and support of the heel.

(3) Navicular—situated at the medial side of the tarsus and just anterior to the calcaneus.

(4) First cuneiform—situated at the medial side of the foot and just anterior to the navicular.

(5) Second cuneiform—wedgelike in form, is situated just lateral to the first cuneiform.

(6) Third cuneiform is situated just lateral to the second cuneiform.

(7) Cuboid—located lateral to the navicular and also lateral to the third cuneiform, anterior to the calcaneus and posterior to the fourth and fifth metatarsal bones.

b. Articulations of the ankle. The talus articulates with the tibia, fibula, calcaneus, and navicular. The first, second, and third cuneiforms articulate with the metatarsals.

174. LEG. a. There are two bones in the leg: tibia and fibula. (See figs. 97 and 98.)

b. Tibia (shin bone) is situated on the medial aspect of the leg. It may be described in terms of the following landmarks:

(1) Medial and lateral condyles—the two eminences extending from the proximal articular surfaces of the tibia.

(2) Intercondyloid eminences—two prominent tubercles projecting upward into the knee joint between the medial and lateral articular surfaces of the proximal end extremity.

Figure 97. Bones of the leg and knee.

(3) Shaft—the main portion, extending between the upper and lower extremities of the bone.

(4) Tibial tuberosity—the large, oblong elevation located anteriorly and between the two condyles.

(5) Medial malleolus—a downward projection at the medial aspect of the distal extremity.

c. Fibula is a slender bone located on the lateral side of the leg. It may be described in terms of the following landmarks:

(1) Head—a conical-shaped projection at the proximal extremity.

(2) Styloid process—the pointed eminence on the head of the fibula.

(3) Lateral malleolus—a pyramidal-shaped process on the lateral side of the distal extremity.

d. Patella (knee cap) is the largest sesamoid bone on the body. It is flat and triangular in shape and is situated in front of the knee joint. (See fig. 99.)

e. Articulations. The tibia articulates with the femur (fig. 97) at the lateral and medial condyles and with the fibula at its lateral condyle forming the knee joint.

175. THIGH. a. The bony framework of the thigh is the femur. (See fig. 100.) It is a long strong bone with a shaft and two extremities. It may be described by the following landmarks:

(1) Head—a hemispherical-shaped prominence at its proximal extremity.

(2) Neck—a constricted portion which connects the head with the shaft.

(3) Greater trochanter—a large, irregular tuberosity situated anterolaterally at the junction of the neck with the upper part of the shaft.

(4) Lesser trochanter—a smaller, irregular tuberosity which projects posteromedially from the shaft below the junction of the neck.

(5) Lateral and medial condyles—bony eminences at the extreme distal extremity. They enter into articulation with the articular surfaces of the tibia at the knee-joint.

(6) Lateral and medial epicondyles—tubercles projecting from the condyles.

(7) Patellar surface—the smooth, shallow depression between the condyles.

(8) Intercondyloid fossa—the deep notch on the posterior aspect between the condyles.

b. Articulations of the femur. The head of the femur articulating with the acetabulum of the innominate bone forms the *hip-joint.* It is classified as a diarthrodial articulation of the ball-and-socket type. It is capable of engaging in flexion, extension, adduction, abduction, circumduction, and rotation of the limb. At its distal end, the femur enters into the formation of the knee-joint. (See fig. 100.)

176. HIP BONE. a. Anatomically, the hip bone is referred to as the "innominate." It is formed by the fusion of what was once three distinct and separate bones; the ilium, ischium, and pubis. (See figs. 101 and 102.)

Figure 98. Bones of the foot and leg.

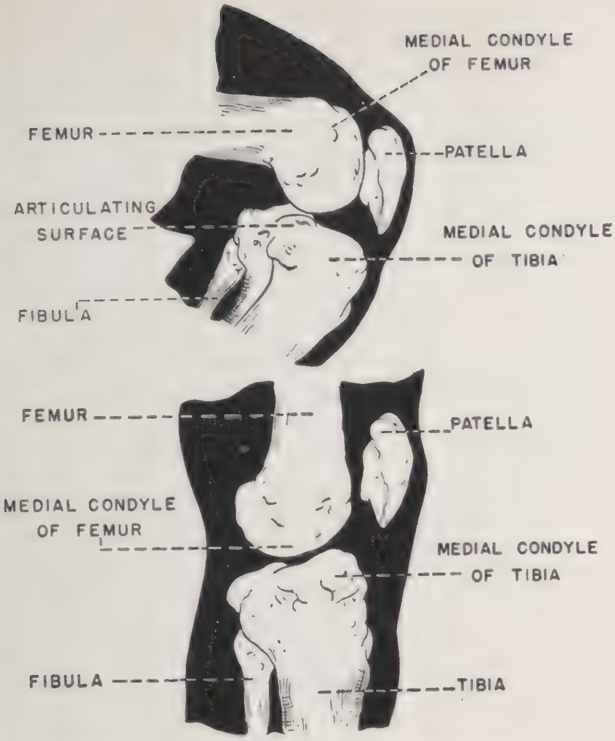


Figure 99. Extension and flexion of the knee joint—lateral view.

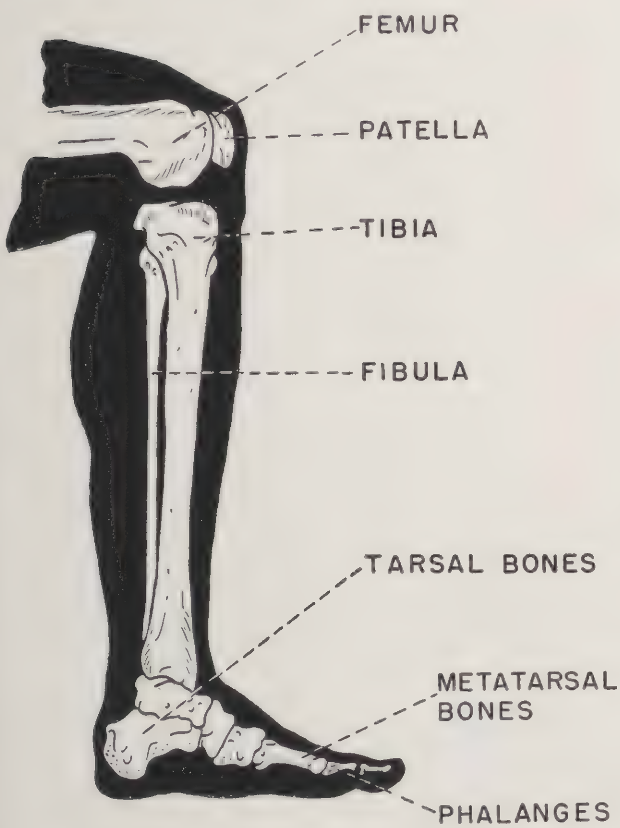


Figure 100. Bones of the foot and leg—lateral view.

b. Ilium comprises the upper portion of the innominate and represents the characteristic broad, wide-flaring portions of the pelvic girdle. It may be described in terms of the following bony landmarks:

(1) Ala—the expanded part which bounds the pelvis laterally.

(2) Iliac fossa—the anterior part of the internal surface of the ala.

(3) Auricular surface—the rough surface located in the inferior portion of the iliac fossa.

(4) Iliac tuberosity—the elevated, rough, superior portion of the iliac fossa.

(5) Crest of the ilium—the uppermost portion.

(6) Anterior superior iliac spine—a projection located at the junction of the crest of the ilium and the anterior border, at the superior aspect.

(7) Anterior inferior iliac spine—a projection situated on the inferior aspect of the anterior border.

(8) Posterior superior iliac spine and the posterior inferior iliac spine—similar prominences situated on the posterior border.

(9) Greater sciatic notch—located below the posterior inferior spine.

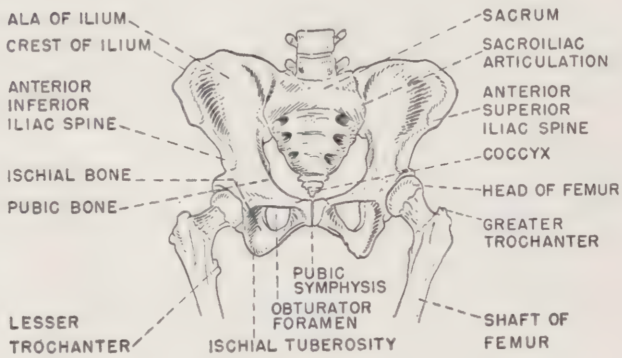


Figure 101.—Pelvic bones—anterior view.

c. Ischium comprises the lower part of the innominate bone. It has a *body*, a *superior*, and an *inferior ramus*. It may be described in terms of the following landmarks:

(1) Ischial spine—a pointed, triangular eminence extending from the medial border.

(2) Lesser sciatic notch—located below the sciatic spine.

(3) Ischial tuberosity—a large elevation on the posterior surfaces of the superior ramus.

d. Pubis forms the anterior portion of the innominate bone. It has a *body*, a *superior*, and *inferior ramus*. It has the following bony characteristics:

(1) Iliopectineal eminence—a rough eminence at the site of fusion between the ilium and the body of the pubis.

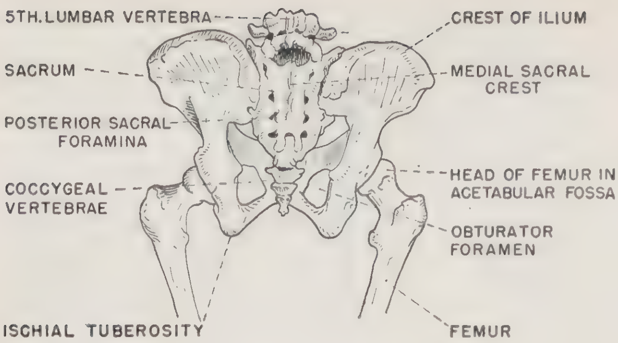


Figure 102. Pelvic bones—posterior view.

(2) Pubic tubercle—a prominent tubercle on the upper border of the superior ramus.

(3) Obturator crest—the lower ridge which passes downward on the superior ramus in front of the acetabular notch.

e. Acetabulum of the hip bone—the site where the three bones of the innominate fuse. The ilium contributes two-fifths to its formation, the ischium, two-fifths and the pubis, one-fifth.

f. Obturator foramen—a large, oval-shaped foramen located between the ischium and pubis.

g. Pubic symphysis—the ligamentous and cartilaginous union of the anterior extremities of the two pubic bones.

h. Articulations of the innominate. The three bones of the innominate, namely the pubis, ilium, and ischium articulate at the acetabulum. This joint may be classified as synarthroidal due to its lack of motion and complete fusion. The acetabulum and head of the femur form the *hip-joint.* The pubic symphysis is an amphiarthroidal articulation because slight motion is possible between the junction of the pubic bones. The articulation of the auricular surface of the sacrum with that of the ilium also forms an amphiarthroidal joint, referred to as the "sacroiliac articulation."

i. Pelvic girdle. The pelvic girdle is composed of the two innominate bones, the sacrum and the coccyx. The pelvis is divided into two portions by the pelvic brim. The expanded part above the pelvic brim is referred to as the "major pelvis" or the "false pelvis." The part of the cavity which is below the pelvic brim is known as the "true pelvis."

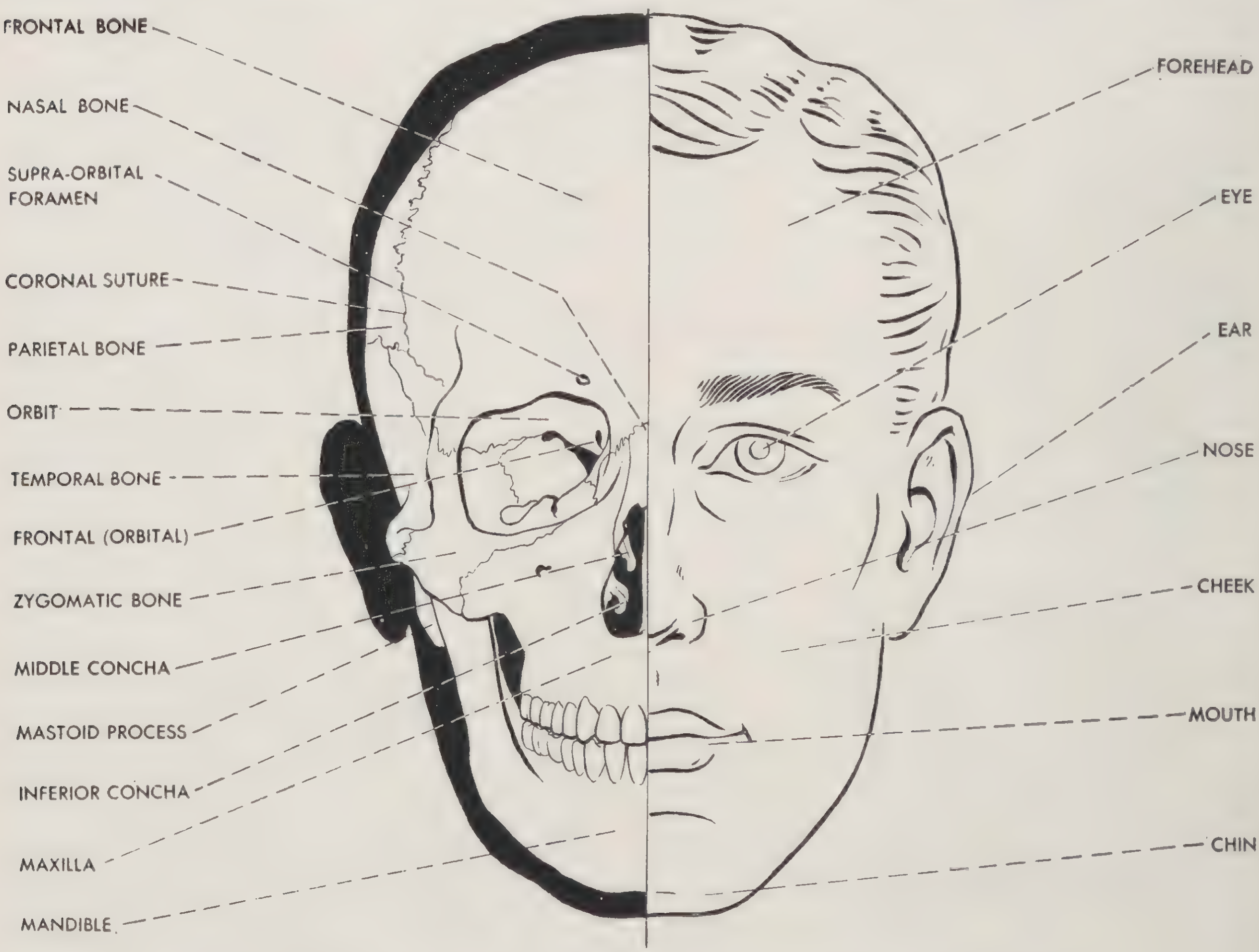


Figure 103. Relationship of soft tissues of head to the skull—anterior view.

177. SKULL. **a.** The skull is supported by the vertebral column. It includes the cranial and the facial bones. (See figs. 103 through 108.) The cranial bones include: 1 frontal, 2 parietal, 1 occipital, 2 temporal, 1 sphenoid, and 1 ethmoid. The facial bones include: 2 maxilla, 2 zygomatic, 2 nasals, 2 lacrimal, 1 vomer, 2 inferior nasal concha, 2 palatines, and 1 mandible.

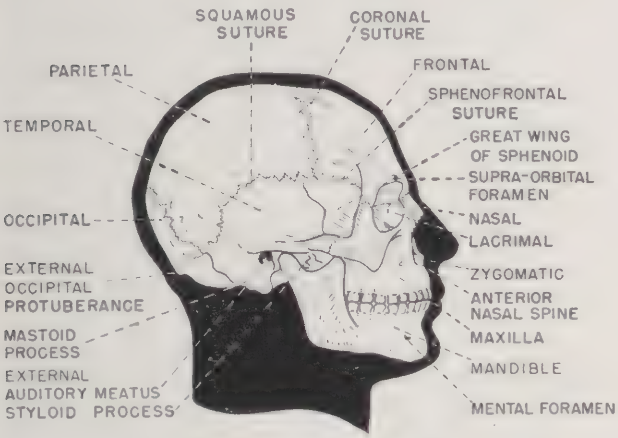


Figure 104. Relationship of soft tissues of head to the skull—lateral view.

b. The cranium is composed of a number of bones which are united with each other by sutures. (See fig. 105.) It serves to support and protect the brain.

(1) Frontal bone forms the forehead and enters into the formation of the orbits (eye sockets) and the nasal cavity. Between the two tables of bone above this margin are located the *frontal air sinuses.*

(2) Parietal bones enter into the formation of the roof and sides of the cranial cavity. On the top of the cranium, the parietal bones are separated from each other by the *sagittal suture* and passing laterally on each side, the *coronal suture,* anteriorly, separates the parietal from the frontal bone. Laterally, the *parietal suture* separates the parietal from the temporal bone. Posteriorly, the occipital is separated from the parietal by the *parieto-occipital suture.*

(3) Occipital bone forms a large part of the base of the cranium and is especially characterized by the large *foramen magnum* which permits the spinal cord to pass from the vertebral canal to the cranial cavity. On each side of the foramen are the *condyles* that allow for articulation of the skull with the supporting member of the cervical portion of the vertebral column—the *atlas.* Externally, on the posterior surface, is a distinct projection known as the "external occipital protuberance." Internally the occipital bone contributes to the formation of the cranial fossae and the walls are marked by deep grooves for the passage of the cranial blood sinuses which drain the venous blood from the brain.

(4) Temporal bones are paired and each consists of *squamous, mastoid,* and *petrous portions.* Between the tables of bone of the mastoid process are located the *mastoid air cells.* Within the petrous portion are situated the essential organs of hearing and equilibrium, and, opening internally, is the *internal auditory* meatus where an opening exists for accommodating the 7th and 8th cranial nerves. Externally, an opening is provided in the tympanic portion called the "external auditory meatus" which allows sound waves to stimulate the structures of the middle ear. Projecting downward from the temporal bone is a slender spine known as the "styloid process." Within the middle ear are situated the *auditory ossicles.* These serve to conduct the sound vibrations from the ear drum (tympanum) to the inner ear.

(5) Sphenoid bone is located at the base of the skull. The upper part of the body of the sphenoid presents a depression resembling a Turkish saddle called the "sella turcica" or "hypophyseal fossa" where rests the pituitary gland. Beneath this depression are the *sphenoidal air-sinuses*—one of the paranasal sinuses.

(6) Ethmoid is an extremely light bone situated at the base of the cranium. It takes part in the formation of the medial wall of the orbit, the septum of the nose and the roof and lateral wall of the nasal cavity. The *cribriform plate* is a horizontal portion of bone perforated for the passage of the olfactory nerves. It is located in the midline between the orbital plates of the frontal bone. Extending from the midline of it, within the anterior cranial fossa, is the *crista galli* to which the meninges of the brain are attached. The upper part of the nasal septum is composed of the *perpendicular plate of the ethmoid.* The two *lateral masses* of the ethmoid comprise the *ethmoidal air cells,* which constitute one set of *paranasal sinuses.*

(7) The auditory ossicles, *incus, malleus, stapes,* are located within the middle ear.

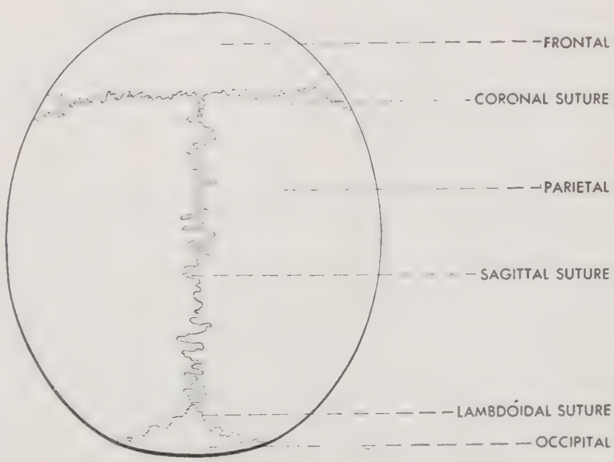


Figure 105. Calvarium—superior view.

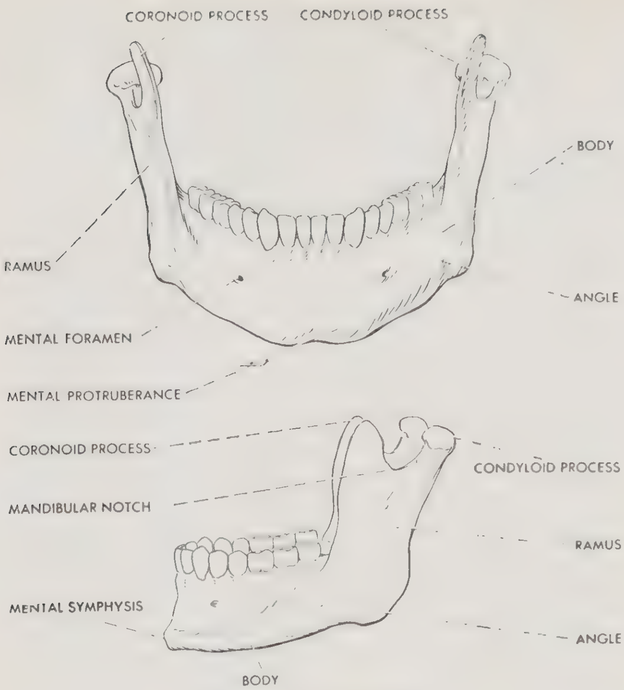


Figure 106. Mandible.

c. The facial bones, by their union, assist in the formation of the remaining portion of the skull. They serve as supporting framework for the upper portion of the digestive and respiratory systems.

(1) Maxillae are the large bones contributing prominently in the formation of the upper jaw, roof of the mouth, floor and lateral wall of the nose, and floor of the orbit. They serve as foundation for all the upper teeth. The sites of attachment of the teeth form slight, bony eminences called "alveolar processes." The articulations of these processes form the *alveolar arch* opening on the outer surface of the maxilla. Below the orbit is the *infra-orbital foramen* through which passes the infra-orbital nerve carrying sensory impulses from the adjacent facial area. Within the body of the bone is a large cavity, extremely thin boned, known as the "maxillary air sinus" or the "antrum of Highmore," another of the paranasal sinuses. It communicates by two small apertures with the middle meatus of the nose.

(2) Zygomatic or malar bones form the promentories of the cheek and lateral wall of the orbit. Together with the zygomatic process of the temporal bone, they form the *zygomatic arch.*

(3) Nasal bones are the small bones that comprise the upper part of the bridge of the nose. The lower part is formed by cartilage.

(4) Lacrimals are the two small fragile bones situated at the medial wall of the orbit which assist in the formation of the *nasolacrimal duct* leading from the orbit to the nasal cavity.

(5) Vomer is a thin, flat, keel-like bone which forms the lower part of the *nasal septum.*

(6) Inferior nasal conchae are two, curved, shell-like structures lying horizontally in the lateral wall of the nasal cavities.

(7) Palatine bones are two, **L**-shaped bones which together with the palatal process of the maxilla unite to form the roof of the mouth. They also form the floor of the orbit.

(8) Mandible, the strongest and largest bone of the face, is the horseshoe-shaped bone forming the lower jaw. (See fig. 106.) On the external surface of the body is the *mental protuberance;* the upper border, called the "alveolar process," supports the teeth. Extending upward, posteriorly, at each side is a *ramus* which projects as a *coronoid process* (affording muscular attachment) and a *condyloid process* (which enters into the formation of the *temporomandibular joint*). On the internal surface of the ramus is the *mandibular foramen* through which passes the dental nerve carrying sensory impulses from the teeth of the lower jaw to the sensory area of the brain.

(9) Hyoid bone is a **U**-shaped bone located just above the "Adam's apple," serving as a point attachment for the muscles associated with the tongue, pharynx, and the anterior part of the neck.

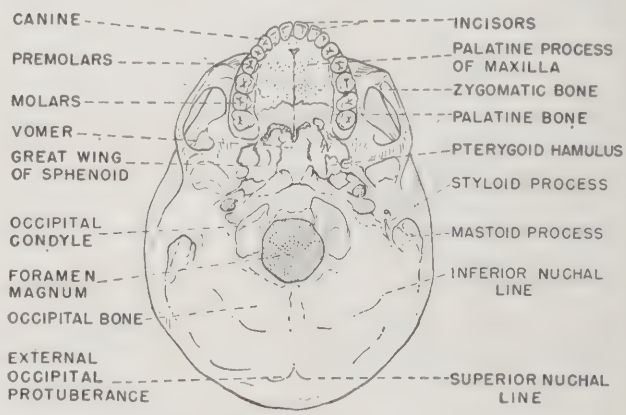


Figure 107. Skull—inferior view.

178. VERTEBRAL COLUMN. a. General. The vertebral column or spine is the central part of the axial skeleton. It serves to support the head, the ribs, and the extremities. It assists the abdominal muscles in supporting the viscera. There are seven cervical, twelve thoracic, five lumbar, five sacral, and four coccygeal vertebrae, totaling 33 in all.

b. General characteristics of a vertebra. A typical vertebra consists of an anterior portion, the *body,* and posterior part, the *vertebral arch.* The *vertebral arch* consists of two *pedicles* or roots and two *lamina;* it has seven processes, four *articular,* two *transverse* and one *spinous.* It encircles the *vertebral foramen* through which passes the spinal cord. An *intervertebral disk,* composed of fibrocartilage, forms an

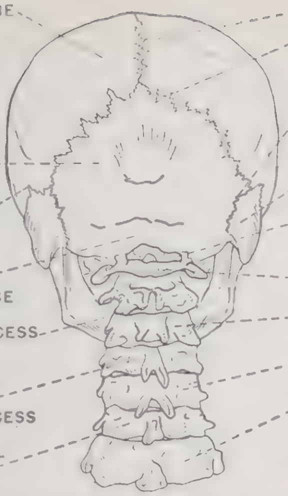


Figure 108. Skull and cervical vertebrae—posterior view.

amphiarthrodial articulation between the bodies of the vertebrae. The notch of a lower vertebra in apposition with that of an upper vertebra unites to form an *intervertebral foramen* through which pass the spinal nerves.

c. Features of the spinal column. In the cervical region (fig. 108) the first vertebra is known as the "atlas." It serves as the articulating surface between the rest of the spinal column and the condyles of the skull. This vertebra rotates upon the second vertebra, the *axis*. The anterior portion of the *axis* is elongated by way of the *odontoid process*.

d. In the thoracic region, the vertebrae are all characterized by the fact that they articulate with ribs and contribute to the posterior wall of the thoracic cage.

e. The lumbar vertebrae are the largest of the movable vertebrae. They do not have *costal facets* on the sides of their bodies.

f. The sacrum is a fused, wedge-shaped bone inserted between the two innominate bones.

g. The coccyx consists of a variable number of vertebral segments which extend below the sacral and are the rudiments of what was once a tail.

h. When the vertebral column is viewed laterally it shows four curves. The cervical and lumbar curves are concave forward (*lordosis*) while the thoracic and sacral curves are convex forward (*kyphosis*). (See fig. 109.)

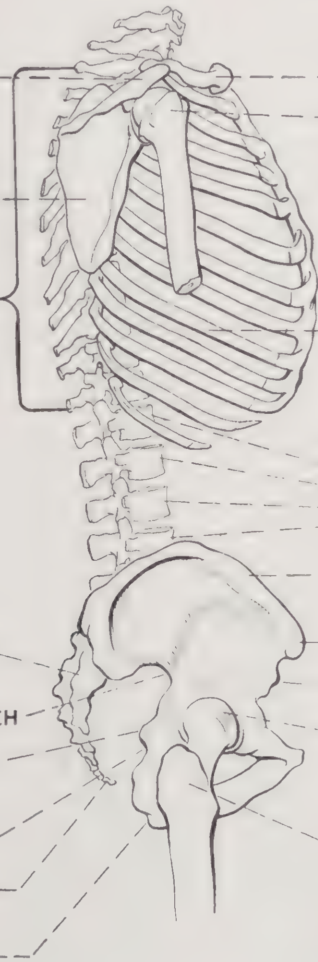


Figure 109. Bones of the pectoral and pelvic girdles—lateral view.

179. RIBS AND STERNUM. **a.** Ribs, twelve pairs, are located on each side of the thoracic cage. (See fig. 110.) The first seven are connected by means of costal cartilages to the sternum and are therefore called "true ribs." In contradistinction the remaining five are called "false ribs." The eighth, ninth, and tenth are joined to the cartilage of the seventh while the eleventh and twelfth ribs are free at their anterior extremities. The latter are therefore commonly called "floating ribs." The junction of the osseous portion of the ribs with their cartilages forms a *synchondrosis.* As age advances, the cartilaginous union is replaced by bone and is then known as "synostoses." Each rib has a *posterior* and an *anterior extremity* connected by a *body* or shaft.

b. Sternum is the flat breast bone located anteriorly and occupying the middle of the thoracic cage. It consists of three parts, the manubrium, corpus sterni (gladiolus), and the xiphoid process.

(1) The manubrium is the upper part. With the sternal end of the clavicle it forms the *sternoclavicular* articulation—a diarthrodial joint. The articulation formed by the first rib and the manubrium is a synarthrodial articulation of the type synchondrosis.

(2) The corpus (gladiolus) is the middle section of the sternum. It articulates with the costal cartilages of the 2d–4th ribs and forms with them diarthrodial joints.

(3) Xiphoid process is a thin variable structure in the lower portion. It is cartilaginous during the earlier ages but develops into bone as age advances.

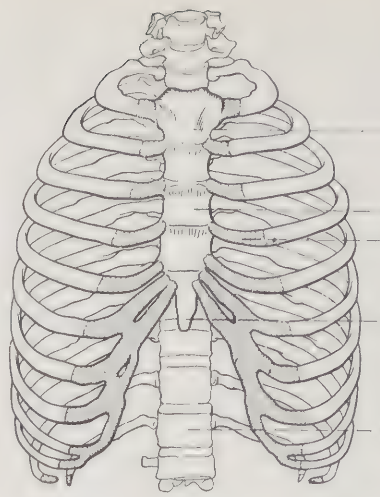


Figure 110. Thoracic cage—anterior view.

SECTION V. DIGESTIVE SYSTEM

180. GENERAL. **a.** The digestive system is composed of the digestive tube (alimentary tract) and its associated appendages or accessory organs situated in the abdomen. (See fig. 111.) Practically all of the food substances ingested by an individual requires some alteration before they can be absorbed into the blood and be conveyed to all parts of the body. This process of conversion of food into assimilable substances constitutes "digestion." It is accomplished with the assistance of enzymes which are secreted by various glands along the tract. The functions of the digestive system include:

(1) Ingestion—accomplished by the mouth.

(2) Mastication—accomplished by the teeth and rendering the substances in a form so that they may be easily acted upon by enzymes.

(3) Insalivation—accomplished by the salivary glands whereby the mass of food becomes lubricated for passage down the tract and thus enables the initial stages of enzyme action to begin.

(4) Propulsion of the food along the tract—accomplished by means of the muscles of deglutition or swallowing in the esophagus and also by the complex movements of the stomach and intestinal tract.

(5) Secretory—accomplished by the various digestive juices of glands, either connected to the tract by ducts or located directly within it. This permits the conversion of the food into its final assimilable form.

(6) Absorption of the final products of digestion—accomplished by the cells of the mucous membrane of the small intestine, colon and the blood vessels.

b. Foods. Foods are classified as carbohydrates, proteins, fats, and vitamins.

(1) Carbohydrates—substances consisting of carbon, hydrogen, and oxygen—as contained in starches and sugars.

(2) Proteins—complex substances which contain nitrogen in addition to carbon, hydrogen, and oxygen—as contained in meats, nuts, and certain vegetables.

(3) Fats—a more concentrated form of energy food, containing the same elements as carbohydrates but in different combination.

(4) Vitamins are complex organic substances. They are not nutritious in themselves but are essential for normal health. Included are:

(*a*) Vitamin A—promotes growth and increases resistance to infections. Night blindness is associated with deficiency of this vitamin.

(*b*) Vitamin B—promotes appetite and aids in the maintenance of the motility of the intestinal tract. It provides for the proper functioning of the nervous system. It is of a multiple nature and is referred to as the "Vitamin B Complex."

(*c*) Vitamin C—stimulates the proper functioning, maintenance of growth of teeth and bones.

(*d*) Vitamin D—influences blood calcium and mineral metabolism.

(*e*) Vitamin E—essential for normal reproduction

of the germ cells in the male and for the development of the placental membranes in the female.

(*f*) Vitamin G—contains a growth factor.

c. Enzymes are chemical substances formed by living cells. They are complex organic compounds capable of producing, by their presence, a catalytic action involving the transformation of some other compound without themselves being affected.

d. The alimentary tract extends from the mouth to the anus and is lined throughout its extent with mucous membrane. It is about 28 feet long and is divided into the following parts:

(1) Mouth cavity—includes the: salivary glands, teeth, tongue, and tonsils.

(2) Pharynx.

(3) Esophagus.

(4) Stomach.

(5) Small intestine—includes the: duodenum, jejunum, and ileum.

(6) Large intestine—includes the: cecum, ascending colon, transverse colon, descending colon, and sigmoid colon.

(7) Rectum.

(8) Anus.

e. The accessory organs which contribute to the process of digestion are: the liver, gall bladder, and pancreas.

181. MOUTH CAVITY. The site of commencement of the digestive tube, where the food is ingested. It is composed of the mouth cavity proper and the vestibule. The *vestibule* is bounded externally by the lips and cheeks, internally by the teeth and gums.

182. SALIVARY GLANDS. These include three pairs: the submaxillary, the sublingual and the parotid together with numerous glands located in the mucous membrane of the oral cavity. All of these glands contribute to the formation of saliva.

a. Parotid gland is an irregular, lobated gland situated in front of each ear. By means of *Stensen's duct* the serous secretions of it are secreted through the muscles of the cheek into the mouth, through a small papilla which is located adjacent to the second upper molar tooth.

b. Submaxillary gland is rather irregular in form, shaped like a walnut, and lies close to the internal surface of each half of the mandible. By means of *Wharton's duct,* it conveys secretions into the mouth opening through a small orifice at the side of the *renulum* of the tongue.

c. Sublingual gland is the smallest of the three salivary glands. The pair are situated just anterior to the base of the tongue. They empty directly into the oral cavity by means of many ducts or into the *submaxillary duct.*

d. Function of the saliva. The quantity of saliva secreted daily averages about 1500 cc. It contains an amylolytic ferment (starch digesting) ptyalin and some maltase. Its chief value is in the process of *insalivation,* that is, to moisten food, bring taste components into solution and lubricate the bolus or food mass for swallowing.

e. Excitation of salivary flow. The flow of saliva is activated by: the stimulation of the 5th and 7th cranial nerves by the presence of the food in the mouth; reflex stimulation of the salivary glands by

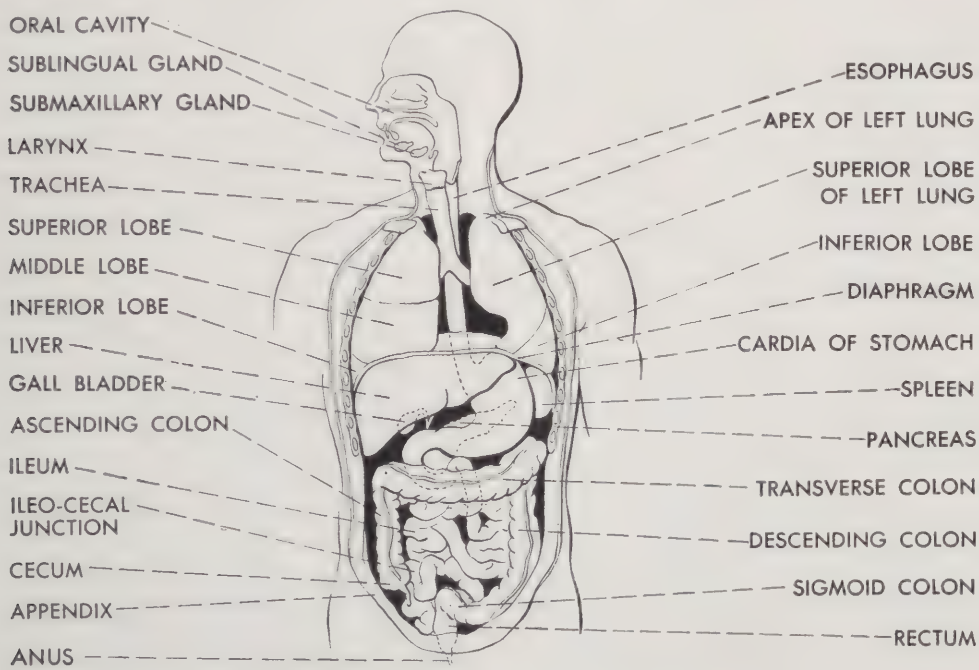


Figure 111. Digestive system and associated organs.

way of the autonomic nervous system—exciting a thick secretion and direct stimulation of these glands by the brain because of the sight, thought, or smell of food—producing an abundant though thin secretion.

183. TEETH. **a.** There are two sets of teeth. The first, is the temporary set which is referred to as the *deciduous* or *milk* teeth. These appear during the first and second years. The second set, called the permanent teeth, begin to replace the deciduous set about the sixth year and are usually completely developed about the twenty-fifth year.

b. There are 20 deciduous teeth, including 4 incisors, 2 cuspids, and 4 molars in each jaw.

c. There are 32 *permanent* teeth, including 4 incisors, 2 cuspids, 4 bicuspids, and 6 molars in each jaw. (See fig. 112.)

d. Characteristics of teeth. Each tooth consists of three portions: the *crown* projecting beyond the gingiva; the *root* which is embedded in the alveolus (bony ridges) and the *neck* which is the constricted portion between the crown and the root.

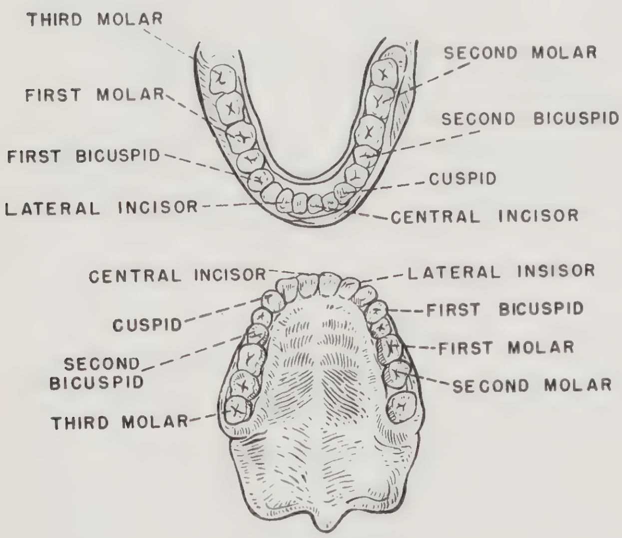


Figure 112. Arrangement of the teeth.

184. TONGUE. It is a muscular organ intimately associated with the functions of taste, speech, mastication, insalivation, and deglutition. The varied movements of the tongue are controlled by four pairs of muscles. The tongue is covered with mucous membrane which contains secreting cells and taste buds. There are three varieties of taste buds: *fungiform*—located near the edges of the tongue; *filiform*—which are widely distributed and *circumvallate*—which are largest and fewest and are located at the posterior ridge of the tongue.

185. TONSILS. The common name, tonsil, is applied to any small masses of lymphoid tissue. The *lingual tonsils* are located underneath the tongue; the *pharyngeal tonsils* (commonly called the *adenoids*), and the *palatine tonsils* (the two ordinarily considered in using the term "tonsil") are located on the lateral wall of the oral part of the pharynx just above the palate.

186. PHARYNX. It is the continuation of the digestive tube behind the mouth and extending into the esophagus. It consists of three parts: the *nasopharynx*—which lies behind the nose and above the level of the *soft palate*—the adenoids of childhood are located on its posterior wall; the *oral pharynx*—which continues from the soft palate to the level of the hyoid bone and the *laryngeal pharynx*—is the portion extending with the esophagus from the hyoid bone to the lower border of the cricoid cartilage of the larynx.

187. ESOPHAGUS. It is a musculomembranous tube, about 10 inches long and ½ to 1 inch in diameter, extending from the end of the pharynx to the cardiac orifice of the stomach.

188. STOMACH. **a.** It is a pear-shaped organ situated between the end of the esophagus and the beginning of the small intestine. (See fig. 113.) It has an *anterior* and *posterior surface.* The upper border is called the *lesser curvature* while the lower border is known as the *greater curvature.* The opening of the esophagus into the upper portion of the stomach is known as the *cardia* and the opening into the intestine is referred to as the *pylorus.* The *fundus* is the expanded portion which bulges upward and to the left.

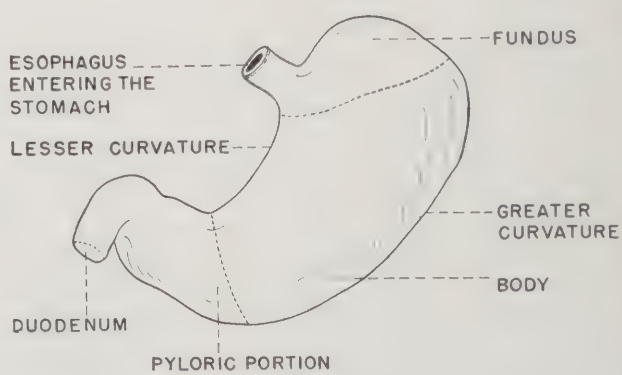


Figure 113. Stomach.

b. Gastric secretion. Gastric juice, which is acid in reaction and of sour taste, is secreted by the cells in the wall of the stomach. It contains hydrochloric

acid. The enzyme *pepsin* is also secreted by cells in the wall. It starts the digestion of proteins after being activated by the hydrochloric acid. A third enzyme which is secreted is *rennin* which serves to coagulate milk.

189. SMALL INTESTINE. a. It is a tube, from 22 to 25 feet long, beginning at the pylorus and ending at the ileo-cecal junction. It consists of the duodenum, jejunum, and ileum.

b. Duodenum—9 to 11 inches long and forms a C-shaped curve, encircling the head of the pancreas. The pancreatic duct and the common bile duct open into it.

c. Jejunum—comprises the upper two-fifths of the rest of the small intestine and is thrown into numerous curves.

d. Ileum—the remaining three-fifths of the small intestine. It opens into the ascending colon at the *ileo-cecal valve*.

190. LARGE INTESTINE. a. It is composed of the cecum, ascending colon, transverse colon, descending colon, and the sigmoid colon.

b. Cecum—a blind sac located in the right iliac fossa. Extending from the cecum is the *vermiform appendix*.

c. Ascending colon—extends from the cecum to the transverse colon. It is about 8 inches long and comes into contact with the under surface of the liver. This portion is called the "hepatic flexure."

d. Transverse colon—variable in position, extending to the under surface of the spleen. The curved portion here is called the "splenic flexure."

e. Descending colon—about 6 inches long, extending down in front of the left kidney to the pelvis.

f. Sigmoid colon—extends as an S-shaped loop from the descending colon to the rectum, passing over the pelvic brim into the true pelvis.

191. RECTUM. It is about 6 to 8 inches long and passes downward in the curve formed by the sacrum and coccyx. It terminates in the lower end of the tract as the *anus*.

192. MOVEMENTS OF ALIMENTARY TRACT. a. In a great measure, the extent of our knowledge of the alimentary tract is due to the application of contrast media in roentgenographic studies. (See app. II.) The most common medium used is *barium sulphate* which may be given by mouth (barium meal) or by rectum (as a barium enema). Much information might be gained by these studies, such as: the rate of passage of the barium, the position, condition and contour of the organs and possibly, the presence of pathological conditions.

b. Stomach. Normally, within a few seconds after the barium meal reaches the stomach, it passes through the pylorus. After the first hour, the stomach is usually half empty and by the sixth hour, none of the barium should be left.

c. Small intestine. The barium should reach the ileo-cecal valve within 2 hours. At the end of 6 hours, a large part of it should have passed into the cecum. In 12 hours, none of the barium should remain in the small intestine.

d. Colon. At about 24 hours, the meal should reach the rectum. Usually, in normal health, the colon may be empty in 48 hours, though it may still be visualized for more than 100 hours.

193. LIVER. a. It is the largest gland in the human body. It is located in the right hypochondrium and upper epigastric regions and extends for a short distance into the left hypochondrium. It is held in place by ligaments. The *falciform ligament* attaches it to the anterior abdominal wall and divides the liver into a *right* and left lobe. The left portion of the right lobe is subdivided into two smaller lobes the *quadrate* and *caudate*.

b. The excretory apparatus of the liver consists of—

(1) The hepatic duct—which leaves the liver at the *porta hepatis*. It is formed by the union of the two main ducts concerned with the right and left lobes.

(2) The gall bladder—which serves as a reservoir for the bile.

(3) The common bile duct—which is formed by the *hepatic duct* and the *cystic duct* (gall bladder duct).

c. Functions of the liver:

(1) Secretion of bile—which serves to break down fats. This secretion is normally continuous; when not directly passed into the digestive tract, it accumulates in the gall bladder where it is concentrated and stored for future use.

(2) Glycogenic function—which involves the deposition of glycogen (animal starch) within the liver cells. It is also concerned with *glycogenolysis*—that is, breaking the glycogen down into glucose again for the metabolic requirements of the body.

(3) Protein metabolism—the function concerned with action on proteins; the formation of urea and the destruction of uric acid. In this way the liver detoxifies for if uric acid is allowed to accumulate, it becomes toxic to the body.

(4) Fat metabolism—a very complex biochemical process concerned with fatty acids, glycerol, etc.

194. GALL BLADDER. It is a pear-shaped sac situated in a fossa on the under surface of the liver. It is composed of an expanded end, the *fundus*, a *body*, and a *neck* which is constricted to form the *cystic duct*. Roentgenographically it can be visualized by the administration of a dye such as tetraiodophenolphthalein.

195. PANCREAS. **a.** It is an elongated organ shaped like a pistol with the muzzle pointing toward the hilum of the spleen. It is composed of a *head, neck, body*, and *tail.* It occupies a position beneath the stomach. It furnishes pancreatic juice which is secreted by one or two ducts (*Wirsung and Santorini*).

b. Function of pancreas:

(1) Produces a pancreatic secretion which is capable of splitting all three classes of foodstuffs, that is, carbohydrates, fats, and proteins.

(2) Produces a hormone, *insulin,* which is secreted into the blood and acts to convert blood sugar into glycogen.

SECTION VI. RESPIRATORY SYSTEM

196. GENERAL. **a.** Respiration (breathing) is a process common to all forms of animal life. It consists of supplying oxygen to the cells of the body and relieving them of the carbon dioxide formed during the burning of foods.

b. Anatomically, the respiratory system is composed of: the nose, paranasal air sinuses, mouth, pharynx, larynx, trachea, bronchi, and lungs.

197. NOSE. **a.** It is the organ of smell. It is composed of an outer or external portion and an internal portion. The framework of the external nose is composed of the nasal bone and a greater amount of cartilage.

b. The nose has a dual function:

(1) Olfactory function—which is accomplished by the fine distribution of the branches of the first cranial nerve which pass through the foramina of the cribriform plate of the ethmoid and are distributed to the upper portion of the nasal septum.

(2) Respiratory function—which is carried out by means of a mucous membrane, richly supplied with blood, serving thereby to warm and moisten the inspired air. In this region also there are located many fine hairs called "cilia." When they are moist, they catch dust particles in the inhaled air and thus serve as filters.

198. PARANASAL SINUSES. **a.** They are located in the skull and vary in form and size in different individuals. The walls of each sinus are covered with mucous membrane from which cilia extend. These include the—

(1) Frontal air-sinuses—two in number. They are situated behind the superciliary arches. By means of the *frontonasal duct,* they drain into the middle meatus of the nose.

(2) Ethmoidal air-sinuses—which consist of many thin-walled cavities, honeycomb in structure; they are frequently referred to as air-cells. They lie in the upper portion of the nasal cavity and are separated from the orbit by the thin plate of the ethmoid.

(3) Sphenoidal air-sinuses—two in number, located behind the nasal cavities and situated within the body of the sphenoid bone beneath the sella turcica. They drain into the posterior portion of the middle nasal meatus.

(4) Maxillary air-sinuses—referred to as the antrum of Highmore and are located within the body of the maxillary bones. They, too, drain into the middle meatus. The roots of the upper teeth extend up into the floor of these sinuses.

b. Function of the paranasal sinuses includes: regulation of temperature and moisture of the inspired air, filtering foreign particles, acting as resonance chambers, affecting voice tone and they lighten the weight of the skull.

199. LARYNX. It is the organ of voice and is situated in the upper anterior part of the neck above the trachea. It is composed of nine cartilages; *thyroid, cricoid, epiglottis, two arytenoids, two corniculate,* and *two cuneiform.* With the onset of puberty, the cartilages begin to ossify; as age advances, they may be completely changed to bone.

200. TRACHEA. It is a tube (the wind-pipe) which carries the air between the larynx and the bronchi. It is about 5 inches long and lies partly in the neck, partly in the thorax. It begins where the larynx ends. Cartilaginous rings serve for support of its walls.

201. BRONCHI. They are the two tubes extending beyond the trachea. Their structure is identical with that of the trachea. The primary bronchi divide into *secondary bronchi* and with further divisions they become smaller and smaller, eventually becoming *bronchioles.* The bronchioles divide into the *terminal bronchioles* within the lungs and then divide further into *atria.* Each of these atria then communicate with *air sacs* into which the *alveoli* open. It is here that the exchange of gases takes place.

202. LUNGS. They are composed of two pyramidal, spongy lobes adapted to the function of oxygenating the blood. The lungs are covered with a membrane known as the *visceral pleura.* There is a second layer of pleura adjacent to the thoracic wall—the *parietal pleura.* Between the layers of parietal and visceral pleura is the *pleura cavity* which normally contains a small amount of serous fluid. The pleural cavity is part of the *thoracic cavity.* The lungs, heart, and associated structures lie in the thoracic cavity. The surfaces of the lungs are the *diaphragmatic* (base), *costal* (adjoining the ribs) and *mediastinal* (medial aspects). The *hilum of the lung* is the area through which the essential structures enter the lung. The *apex of the lung* is the rounded portion extending up toward the neck. The right lung contains three lobes, *superior, middle,* and *inferior* partially divided by two fissures. The left lung usually contains only two lobes, *inferior* and *superior.*

203. MECHANICS OF RESPIRATION. The interchange of gases, that is, oxygen and carbon dioxide, is accomplished by inspiration, expiration, and the rest phase of the respiratory cycle. The coordinated movements of the lungs, diaphragm, abdomen, and associated muscles regulate the cycle. In a normal adult, the *respiratory cycle* occurs about 14 to 18 times a minute.

204. LUNG CAPACITY. The amount of air in the lungs varies in accordance with many factors. The volume of air which is inhaled and exhaled during ordinary respiration is approximately 500 cc. This is called the "tidal air." By taking a deep breath, it is possible to inhale an additional 1500 cc.—called "complimental air." Following a normal expiration and inspiration, it is possible to exhale, by deep expiration, about 1500 cc. in addition to the tidal air. This is called "supplemental air." The vital capacity of a normal adult is therefore about 3500 cc. of air, including tidal, complimental, and supplemental air. The air which remains in the lungs after deep expiration is the "residual air." It cannot be removed by voluntary effort. "Minimal air" is the air which is always present in the alveoli even after collapse of the lungs. The air present in the air passages, such as the larynx, trachea, and bronchi is called the "dead space air" and amounts to about 100 cc.

205. CONTROL OF RESPIRATION. Respiration is controlled by the nervous system and by chemical factors. Nervous center for control of the action of muscles coordinated in respiration is located in the medulla oblongata of the brain. This is called the "respiratory center."

206. ARTIFICIAL RESPIRATION. Prompt and intelligent application of the artificial means of respiration will result in saving the lives of many afflicted by the cessation of respiration due to electrical shock, drowning, asphyxiation, carbon monoxide poisoning, and many other causes. Resuscitation may be accomplished even when the heart has stopped; but in order for it to be effective complete anemia or loss of blood to the brain must not exceed 7 to 10 minutes. Therefore in order to be effective, artificial respiration must be instituted promptly. (See Schaefer method, par. 103.)

SECTION VII. UROGENITAL SYSTEM

207. GENERAL. a. The urogenital system consists of the organs specialized for secretion and discharge of urine and the genital organs concerned with the process of reproduction. (See fig. 114.)

b. The urinary organs include the: kidneys, ureters, urinary bladder, and urethra.

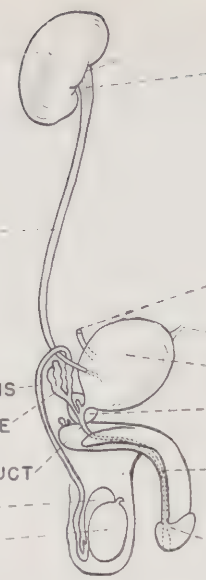


Figure 114. Urogenital system of the male.

c. The genital organs (male) include the: testes, epididymis, ductus deferens, seminal vesicles, ejaculatory ducts, prostate, and penis.

208. Kidney. There are two kidneys. Each has the shape of a bean. They are located in the posterior part of the abdomen, one on each side of the vertebral column and beneath the diaphragm. The right kidney is usually slightly lower than the left. On the medial border of each kidney is the *hilum.* This leads to the *sinus of the kidney* which expands into the *renal pelves* and *calyces.* The ureter leaves the kidney at the hilum.

209. URETER. It is a tube which leads from the renal pelvis to the urinary bladder. The urine secreted by the kidneys passes through it into the bladder.

210. URINARY BLADDER. It is a sac located in the pelvis which serves as a reservoir for urine; its size varies with the amount of fluid it contains. The capacity is from 120 cc. to 300 cc. When empty, the bladder is shaped like a tetrahedron presenting a *fundus, vertex, superior,* and *inferior surfaces.* Internally, there is a *trigone* which is a small triangular area immediately behind and above the *internal orifice of the urethra.* The *orifices of the ureters* are situated at the posterolateral angles of the trigone.

211. URETHRA. It serves to conduct the urine from the urinary bladder to the exterior of the body and extends about 6 inches in length from the *internal urethral orifice* to the end of the penis. It is divisible into three portions: *prostatic, membranous,* and *cavernous.*

212. GENITAL ORGANS (MALE). **a.** The testes, the reproductive glands in the male, are oval in form and are suspended in the *scrotum* by the spermatic cords. The function of the testes is to produce spermatozoa (the male germ cells). This function commences at puberty and continues throughout life.

b. Epididymis, attached to the posterior surface of the testes, receives all the ducts from the testes.

c. Ductus deferens together with the blood, lymphatic vessels, and nerves comprises the *spermatic cord.* It conducts the spermatozoa from the epididymis to the ejaculatory duct.

d. Seminal vesicles are two sacculated structures which lie behind the bladder. The union of the seminal duct and the ductus deferens forms the ejaculatory duct. The seminal vesicles produce a secretion which serves as an optimum medium for motility of the spermatozoa.

e. Ejaculatory duct is formed by the union of the duct of the seminal vesicles and ductus deferens. It enters the prostate.

f. Prostate is a gland which surrounds the base of the urethra and the ejaculatory duct. Prostate gland secretion facilitates and stimulates the motility of spermatozoa.

g. Penis is composed of the urethra and the cavernous bodies which form the erectile portion. The enlarged conical structure at the end of the penis is the *glans penis,* which is inclosed with a fold of skin—the *prepuce.* The penis and scrotum constitute the *external genitalia.*

h. Semen is the fluid composed of spermatozoa and the various secretions added to it along its passage. Approximately, two to five hundred million spermatozoa are contained in each ejaculation.

213. FUNCTION OF EXCRETORY SYSTEM. The metabolic activity of the body results in the accumulation of waste products. In order for the proper physiological functioning of the body, it is essential that these substances be removed. Some of the products formed in the process of digestion are absorbed into the alimentary tract into the blood and are changed to some extent by the liver. They do not, however, become converted into tissue. This type of waste product is called "exogenous." Other waste products are the result of the breaking down of general body tissue, muscle, nervous tissue, glandular tissue, and blood pigment. This type is referred to as "endogenous."

214. PATHWAYS OF EXCRETION. The principal pathways of excretion are:

a. Skin—the most primitive form of an excretory organ. Two fluids are excreted by the skin, namely *sweat* (perspiration) and *sebum* (oil excretion of the glands attached to the hair roots). Sweat is composed of about 99 percent water, slight amount of sodium chloride (salt) and traces of organic material. Normally, during ordinary weather, about 700 cc. of water leave the skin per day. The ability of the skin to secrete water frequently assists an over-worked or diseased kidney. The main function, however, of perspiration is to assist in the regulation of the temperature of the body.

b. Lungs eliminate chiefly carbon dioxide. Water is also lost through the lungs. The amount exhaled may be about 500 cc. per day if the respiration and temperature are normal. Volatile substances such as ether, chloroform, alcohol, and acetone may also be eliminated by the lungs.

c. Large intestine excretes residue of the food which have escaped digestion. To this are added other substances such as calcium, magnesium, iron, phosphate, which are excreted from the blood and cellular debris and bacteria. This accumulated residue is referred to as the *feces.*

d. Kidney is an important organ for excretion and for the maintenance of the blood composition.

215. MICTURITION. The urine collected in the kidneys passes down through the ureters into the urinary bladder. This is accomplished by contraction waves in the wall of the ureter. Accumulation of urine in the bladder occurs until the pressure is such as to set up nervous impulses associated with a desire to urinate or micturate. This desire results in the relaxation of the muscles controlling the aperture and a contraction of the muscular wall of the bladder. The effect is to expel urine from the bladder into the urethra to the exterior.

216. DEFECATION. As the pelvic colon gradually fills with feces the material passes into the rectum. With increase in pressure, impulses set up the desire to defecate. This is accomplished by relaxation of the muscles of the anus and contraction of the rectal wall. Normally, this act can be prohibited or modified by voluntary control.

SECTION VIII. CIRCULATORY SYSTEM

217. GENERAL. **a.** The circulatory system is composed of the blood-vascular system and the lymphatic system. It is through the blood-vascular system that the blood is pumped and by means of different vessels of varying diameter, the blood is circulated throughout the entire body. (See fig. 115.) The lymphatic system consists of a network of vessels and bodies which collect and transport lymph throughout the tissue spaces in the body.

b. The blood vascular system includes the heart, aorta, arteries, capillaries, and veins.

c. The lymphatic system includes the lacteals of the intestinal walls, the lymph capillaries, the lymphatic vessels, lymph nodes, and spleen.

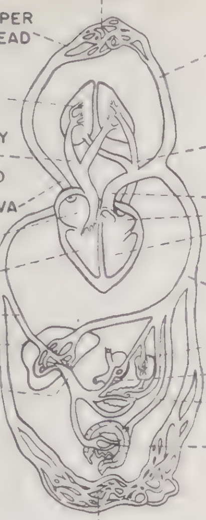


Figure 115. Circulation of the blood.

218. BLOOD—COMPOSITION AND FUNCTION. **a.** Blood is composed of a fluid part, the plasma, and a cellular part distinguished as red corpuscles (erythrocytes), white corpuscles (leukocytes), and blood platelets (thrombocytes). The average blood volume is about 8.8 percent of the body weight or about a gallon and a half for the average adult.

b. Corpuscular elements of the blood. (1) Red blood cells (erythrocytes) are disklike in shape and lack a nucleus. They number 4,700,000 to 6,500,000 for the male and from 4,300,000 to 5,300,000 for the female per cubic millimeter of blood in the average normal adult. The cells exist in the circulation from 18 to 50 days. Estimates indicate that between 600 million and 1.5 billion red cells are destroyed daily dependent upon various chemical, physical, or pathological conditions within the body. Exposure of the body to an excessive amount of X-rays or radium emanations may cause destruction of these cells. (See par. 104.)

(*a*) The most outstanding constituent of the red blood cell is in its coloring matter or *hemoglobin*. The hemoglobin is a protein compound containing iron. The hemoglobin functions as the means of carrying oxygen from the lungs to the tissues.

(*b*) In the adult, the erythrocytes are formed only in the red marrow of bones.

(2) White blood cells (leukocytes) are colorless, nucleated cells extremely variable in shape and number. The average adult has from 7,000 to 9,000 per cubic millimeter of blood. The life span is indefinite and it is estimated that it may be in terms of weeks, days, or even hours. White blood cells are divided into two groups, nongranular leukocytes, and granular leukocytes.

(*a*) Nongranular leukocytes are of three types: *Lymphocytes*—which resemble red cells in size but contain a large spherical nucleus, (they constitute about 20 percent of the total white cells); *transitional leukocytes*—which are about the same size as large lymphocytes and have a nucleus in the shape of a horseshoe (they number about 2 to 4 percent of the white blood cells); *mononuclear leukocytes*—which resemble the large lymphocytes (they constitute about 2 to 4 percent of the white cells).

(*b*) Granular leukocytes or polymorphonuclear leukocytes comprise about 70 percent of the white cells. The nucleus is irregular in shape and appears in three or more lobulations. Three types are recognized by staining as: *eosinophils*—which take an acid stain and show red granulations, *basophils*—which take a basic stain and show blue granulations, and *neutrophils*—whose granulations respond to both acid and basic stains.

(*c*) Function of the white cells is primarily a protective one. They possess the ability to encircle and eliminate foreign particles in the blood and tissues. In the execution of this function, white cells are referred to as *phagocytes* and the phenomenon is known as *phagocytosis*. The ability of the cells to escape through the walls of the capillaries and enter tissue spaces renders them especially useful in combating infections. Any site of infection is usually characterized by a great increase in leukocytes which are attempting to destroy the bacteria.

(3) Platelets are small round bodies numbering about 300,000 per cubic millimeter of blood. Their chief function is concerned with the clotting of blood. The time between the drawing of the blood and its change to a clot varies and is usually from about 3 to 10 minutes and is known as the "coagulation time."

c. Plasma is the fluid portion of the blood and can be separated from the cellular elements of the blood. It contains over one hundred different constituents.

219. HEART. **a.** It is the main organ which forces the blood through the vessels. It is a conical, muscular organ situated in the lower part of the thoracic cavity. Inclosing the heart is a sac called the pericardium. The position and size of the heart may be determined by roentgenoscopy or by making a roentgenogram. (See fig. 116.)

b. Pericardium. It is a double-walled fibrous sac inclosing the heart. The pericardium attached to the heart is the *visceral pericardium* while the outer layer is the *parietal*. A slight space, therefore, exists between the two layers. This is the *pericardial cavity*. It contains a small amount of fluid called pericardial fluid. This fluid serves to reduce friction concerned with movement of the heart.

c. Walls of the heart. They are composed of three layers: an *epicardium* (outer layer)—which is the visceral pericardium, the *myocardium* (middle layer)—which is muscular and the *endocardium* (inner

lining)—which is continuous with the lining of the blood vessels. The endocardium assists in the formation of the valves of the heart.

d. Chambers of the heart. The heart is divided by septa into right and left halves and by a constriction, the coronary sulcus into an upper cavity called the atrium and a lower cavity called the ventricle. Thus the heart consists of four chambers, namely, right and left atria, and right and left ventricles.

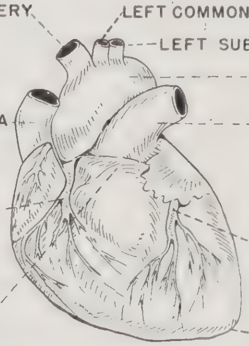


Figure 116. Heart.

(1) *Right atrium.* It is larger than the left. Several vessels carry blood to it. From the upper part of the body, blood is returned by means of the *superior vena cava* while the *inferior vena cava* returns the blood from the lower portion of the body. Blood from the muscle tissue of the heart or myocardium is returned into this chamber via the *coronary sinus.* As the blood accumulates in the right atrium, it passes by way of a large oval aperture, the *right atrioventricular orifice,* into the right ventricle. This opening is guarded by a *tricuspid valve.* The valve consists of three segments and permits the blood to flow from the atrium to the ventricle but normally prevents its flow in the reverse direction, during the contraction of the ventricle.

(2) Right ventricle is the lower right cavity of the heart extending from the right atrium to the apex. It is separated from the left ventricle by the *ventricular septum.* The inner surface of the ventricle is marked by muscular projections (*trabeculae carnae*). From these, extends slender fibers or cords (*chordae tendinae*) which may give rise to *papillary muscles* which function with the heart valves. As the ventricle contracts, the blood (venous) is expelled through the pulmonary artery. Small cuplike valves in the walls of the pulmonary artery (semilunar valves) prevent backflow of the blood.

(3) *Left atrium.* It is separated from the right atrium by the atrial septum. Entering into the atrium are four *pulmonary veins* (carrying arterial blood). The blood is forced into the left ventricle through the *left atrioventricular orifice.* At this opening is located the *bicuspid* or *mitral valve* consisting of two segments. This valve allows the blood to flow into the left ventricle from the left atrium but prevents a flow in the reverse direction during contraction of the ventricle.

(4) *Left ventricle.* It is longer and more conical in shape than the right and forms the apex of the heart. The walls are very thick. The blood (arterial) in the left ventricle is forced out into the systemic circulation of the body through the aorta. *Aortic semilunar valves* (three) allow the blood to flow through the aorta from the left ventricle but prevent it from returning.

e. Blood supply of the heart. Since the heart is in continual action it must be supplied with blood in order to maintain its activities. The blood is supplied by the right and left coronary arteries. Veins return the blood into the coronary sinus and thence into the right atrium.

f. Nerve supply of the heart. The heart is under the control of the involuntary (autonomic) nervous system and an intrinsic automatic nervous system of its own. The *vagus nerve* (parasympathetic division of the autonomic nervous system) inhibits the activity of the heart; it may slow the rate markedly or completely stop it. The *sympathetic nerves* (from sympathetic division of the autonomic nervous system) increases the activity of the heart. Cardiac muscular tissue possesses the power of rhythmic contractility. That is, even if the extrinsic or external nerve supply were severed, the heart would continue to beat.

g. Cardiac cycle. The phase of contraction in the heart is called "systole" while the phase of relaxation is called "diastole." Atrial systole lasts about $1/10$ second while diastole lasts about $5/10$ second.

h. Action of the valves of the heart. The valves of the heart keep the blood flowing in one direction. At the beginning of the contraction of the ventricles, the *atrioventricular valves* close and prevent the passage of blood from the ventricles back into the atria. The *semilunar valves* are forced to open after contraction of the ventricle and the blood thus flows into the pulmonary artery and aorta. When the ventricular contraction (systole) is completed, the semilunar valves are closed by the blood attempting to flow back. At the completion of ventricular systole, the atrioventricular valves open.

i. Pulse rate. The pulse may be ascertained by placing the index finger on an artery. The *radial artery* located on the anterior surface of the distal end of the forearm is usually selected. Other sites may also be used: *superficial temporal pulse,* immediately in front of the ear at the level of the ear; *carotid pulse,* at the level of the lower margin of the thyroid cartilage, along the anterior border of the sternomastoid muscle; *femoral pulse,* in the groin; *popliteal pulse,* in the popliteal space. The *pulse rate*

varies in many individuals depending upon the age, weight, sex, emotional disturbance, and amount of food ingested. Exercise increases the pulse rate temporarily. The rate is faster in women, usually 70 to 80 beats per minute, while in men it is about 65 to 72 per minute. The rate is faster in children than in adults but decreases again as age advances.

j. Blood pressure. The arterial systolic pressure (that is, during the phase of ventricular contraction) can be determined roughly by adding 100 to the age of the individual. However, there are many groups of apparently healthy individuals who do not fall within these limits. During diastole (relaxation of the heart) the pressure falls to about 70 to 90 mm. of mercury. The difference between the arterial systolic and the diastolic pressure is called the "pulse pressure." For example, if the arterial pressure is 120 mm. and the diastolic pressure is 80 mm., then the pulse pressure would be 40 mm. of mercury. The rate and force of the heart beat, the elasticity of the arteries, quantity of blood in the system, and viscosity of the blood are the factors which are involved in the maintenance of blood pressure.

220. ARTERIES. They are the vessels which convey the blood away from the heart. As they divide into many branches, the size of each decreases. The *aorta* is the largest artery in the body. It subdivides into many branches. Arteries are composed of walls which are elastic and extensible.

221. VEINS. They are the vessels which convey the blood to the heart. They are much thinner than the arteries and are more flaccid (less elastic).

222. CAPILLARIES. They are the vessels which convey the blood from the arteries to the veins. *Sinusoids* are fine capillarylike vessels located in the liver and spleen. They are either arterial or venous.

223. CIRCULATION OF BLOOD. **a.** The right side of the heart is venous because it contains the waste products of metabolism and carbon dioxide from the tissues. The venous blood, therefore, enters the right atrium of the heart. From there it is pumped into the right ventricle and leaves by means of the pulmonary artery. The blood in the pulmonary artery is therefore venous and it passes into the lungs. Here, by means of a fine network of capillaries, the carbon dioxide is given off and oxygen is taken up. The pulmonary capillaries give rise to the pulmonary veins which return the oxygenated blood to the left atrium. The blood passes into the left ventricle and is pumped out of the heart through the aorta and distributed by numerous branches to all the tissues of the body (major branch) except the lungs. In the tissues, the arterial blood gives up its oxygen and picks up the carbon dioxide again and carries the venous blood back to the right side of the heart for another cycle.

b. Pulmonary circulation is the passage taken by the blood as it leaves the right ventricle via the pulmonary artery to the lungs and the return of the oxygenated blood to the left atrium of the heart.

c. Systemic circulation is the course taken by the blood from the left ventricle through the aorta and its branches through the body and returning to the right atrium.

224. LYMPHATIC SYSTEM. **a.** Lymph is slightly yellow or colorless. It resembles blood plasma in composition. It contains less protein and coagulates less slowly. Lymph is found in the tissue spaces and contains some lymphocytes.

b. Lymph moves throughout the body by means of a network of capillaries and vessels under the influence of blood and tissue pressure. Chemical substances as well as infections, organisms and other material gain access to the lymphatic system. By means of the *lacteals*, located in the intestinal tract, it is believed that fats are absorbed into the *chyle* or lymphatic vessels where they may undergo a form of synthesis. A great portion of the fat passes into the *thoracic duct* which is the main lymphatic vessel. Commencing from the *cisterna chyli* it passes up from the abdomen into the thoracic cavity adjacent to the bodies of the vertebrae and empties into the left subclavian vein.

c. Lymph nodes are small oval or bean-shaped bodies situated throughout the body in the course of the lymphatic and lacteal vessels, lymph and chyle pass through them on the way to the blood.

225. SPLEEN. It is oblong and flattened in shape and is situated in the left hyponchondriac region lying between the stomach and the diaphragm. The functions of the spleen are not well known. It is supposed to be the organ for the destruction of red blood cells.

SECTION IX. NERVOUS SYSTEM AND ORGANS OF SPECIAL SENSE

226. GENERAL. **a.** The nervous system is that mechanism within the body concerned with integrating the various processes of the individual including the coordination of stimulation received from the environment. The system is divisible into two parts, *central* and *peripheral*. Contained within each division are elements of the *autonomic nervous system*. The organs of special sense such as the eye, the receptors for smelling, for taste and for hearing are considered to be constituents of the nervous system.

b. The central nervous system includes the brain and spinal cord.

c. The peripheral nervous system includes the nerves which extend from the brain and spinal cord and also the more or less detached set, the autonomic nervous system. The autonomic nervous system includes the sympathetic and the parasympathetic groups.

227. COMPOSITION OF NERVOUS TISSUE. a. It is composed of highly specialized tissue sensitive to stimuli and it possesses to a high degree the property of irritability and conductivity. The unit of structure is the *neuron* which consists of a *cell body* and its *processes*. Supporting the neuron are *neuroglial cells* and fibers which comprise the *neural connective tissue*.

b. Neurons are classified according to their function. An *afferent neuron* conveys impulses from the site in the body where the stimulation is received to the central nervous system. An *efferent neuron* conveys impulses away from the central nervous system to a muscle or organ.

228. CEREBROSPINAL FLUID. a. Within the cerebral hemispheres are situated the *lateral ventricles*. There is produced within them a colorless viscid liquid called the cerebrospinal fluid. Each lateral ventricle opens into the *third ventricle* by means of an *interventricular foramen* (foramen of Monro). Additional fluid is added in the third ventricle and through the *aqueduct of Sylvius*, it passes into the *fourth ventricle*. From this point, the fluid enters the *subarachnoid space* through two openings (*foramina of Luschka and Magendie*). The cerebrospinal fluid then passes over the spinal cord and may circulate over the surface of the brain. Some absorption of the fluid may take place by means of small projections or *villi*. The fluid serves as a protective medium for the nerve cells and probably as a means of exchange of metabolic substances. The ventricles can be visualized roentgenographically by the injection of air, lipiodol, or thoratrast into the cavity and by displacement of some of the fluid.

b. Surrounding the brain and spinal cord are three layers of tissue known as the "pia mater," "arachnoid," and "dura mater"; collectively, they are termed the "meninges." The dura mater forms a tough lining closely attached to the skull. The middle layer, the arachnoid, is fibrous while the inner layer, the pia mater, is closely in contact with the surface of the brain.

229. CEREBRUM. It comprises the largest part of the forebrain and consists of two *cerebral hemispheres*. The *cortical* or outer layer of the cerebrum presents many *convolutions* (elevations of brain tissue) or *gyri*, separated from each other by furrows or fissures known as "sulci."

230. CEREBELLUM. It lies behind the pons and medulla oblongata. Its surface is characterized by

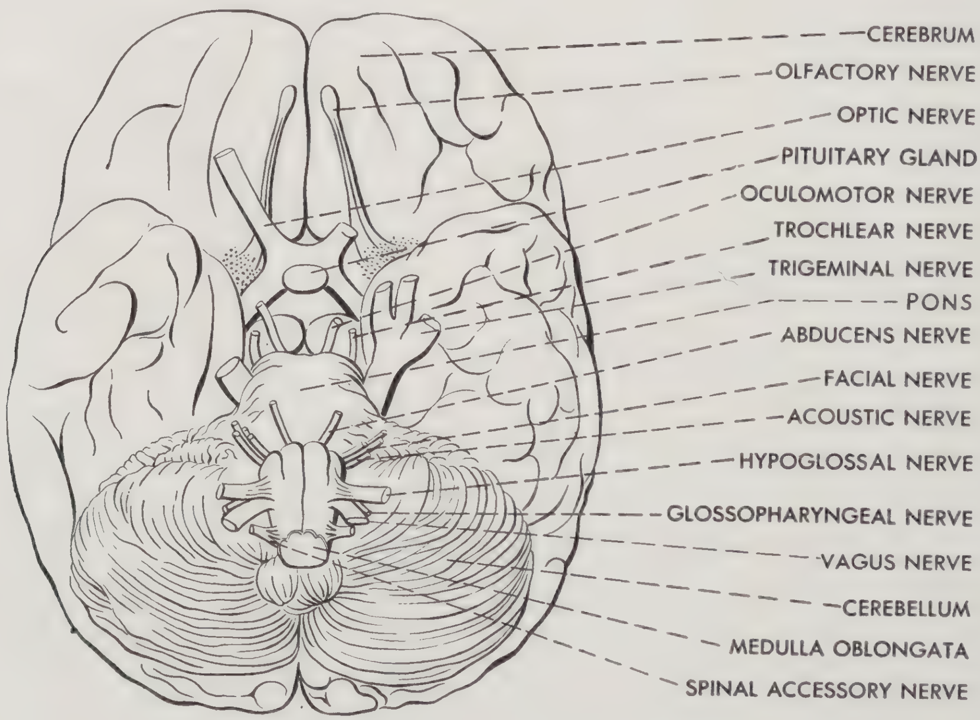


Figure 117. Cranial nerves.

sulci, smaller than those of the cerebrum. The functions of the cerebellum include: regulating muscular tone and muscle balance and serving as a reflex center: a delicate moderator of muscle tone and a center for reflex action. The cerebellum exerts considerable control over posture of the individual. Removal of the cerebellum from animals causes loss of the power of locomotion.

231. MEDULLA OBLONGATA. It extends from the spinal cord to the pons. It is pyramidal in shape. It contains certain groups of cells from which the cranial nerves arise. It also serves as a means of interconnection for the nerve tracts from the peripheral nerves and the cerebellum. Vital centers within the medulla control circulation of the blood, action of the heart and lungs. The mechanism for vomiting and swallowing are also regulated by it.

232. PONS. It is the continuation of brain tissue from the medulla oblongata upward. It contains groups of nuclei giving rise to some of the cranial nerves. Nerve tracts traverse it conveying sensory impulses to the cerebral cortex and motor impulses away to other tissues.

233. SPINAL CORD. It is a continuation of the central nervous system within the vertebral canal extending from the lower level of the medulla oblongata to the level of the 1st and 2nd lumbar vertebrae. If a cross section of the cord is examined, it will be noted that it is composed of *white* and *gray matter*. The latter lies in the interior of the cord in the shape of an H; within the horns of this matter are located the cell bodies. The *posterior horn* contains the *sensory cells* while the *anterior horn* contains the *motor cells*. The white matter surrounds the gray matter and it is composed of bundles of nerve fibers, efferent and afferent, constituting the so-called *nerve tracts* of the cord. If air is injected by means of a "lumbar puncture" into a space between the third and fourth lumbar vertebrae and then into a space between the pia and arachnoid mater called the subarachnoid space, the air will ascend into the ventricles and they may be visualized if a roentgenogram is made of the skull (*encephalography*).

234. CRANIAL NERVES. The cranial nerves are sensory, motor or of a mixed nature and some of the nerves are adapted to special functions. The nerves are attached to the brain (fig. 117) and pass through specific foramina of the skull; they are paired and are listed as follows:

a. The *olfactory nerve* (of smell) conveys the sensation of smell from the mucous membrane in the nose to the *olfactory center* in the cortex.

b. The *optic nerve* conveying the sensation of sight from receptor cells in the retina of the eye to the visual area of the brain.

c. The *oculomotor nerve* which is concerned with the movement of the eye muscles and to a lesser extent with the iris of the eye.

d. The *trochlear nerve* which controls the superior oblique muscle to the eye.

e. The *trigeminal nerve* which arises from a collection of cells known as a ganglion (*semilunar*). It is divided into the *opthalmic, maxillary*, and *mandibular* divisions. The opthalmic nerve carries sensory stimuli from the cornea of the eye and adjacent structures, the skin of the eyelids, eyebrow, nose, and forehead to the ganglion of the 5th. The maxillary nerve conveys sensory impulses from the teeth of the upper jaw, side of the face, lower eyelid, and upper lip. The mandibular nerve conveys sensation from the teeth and gingiva of the lower jaw, the skin of the head, the ear, lower lip, lower part of the face, and mucous membrane of the anterior two-thirds of the tongue. The motor portion of the nerve controls the muscles of mastication.

f. The *abducent nerve* which supplies the lateral rectus muscle of the eye.

g. The *facial nerve* which supplies the muscles of expression of the face, scalp, and ear. Some special type fibers are involved with the autonomic nervous system concerned with secretion of the submaxillary and sublingual glands and taste sensation from the anterior two-thirds of the tongue.

h. The *acoustic nerve* composed of the *cochlear root*, the nerve of hearing and the *vestibular root*, the nerve of equilibration.

i. The *glossopharyngeal nerve* and as its name implies it supplies the tongue and pharynx and conveys taste sensation from the posterior one-third of the tongue. It carries some motor fibers. Via the autonomic nervous system, it supplies the parotid gland with secretory fibers.

j. The *vagus nerve* composed of parasympathetic efferent, motor and sensory fibers. It has an extensive distribution in the body and extends through the neck to the pharynx, larynx, trachea, esophagus, and in general the thoracic and abdominal viscera. It is frequently referred to as the parasympathetic nerve of the body.

k. The *spinal accessory nerve* is essentially a motor nerve supplying two muscles of the neck (trapezius and sternomastoid).

l. The *hypoglossal nerve* controlling the musculature of the tongue.

235. SPINAL NERVES. They arise from the spinal cord and pass through the intervertebral foramina. There are 31 pairs in all and they are divided into 8 *cervical*, 12 *thoracic*, 5 *lumbar*, 5 *sacral* and 1 *coccygeal*. Each nerve is composed of two roots, an *anterior* and *posterior*. A *spinal ganglion* which is a collection of nerve cells is located on the posterior root. Sensory impulses enter the central nervous system via fibers from the periphery of the body

passing through the posterior root. Motor impulses are conveyed out of the cord through the anterior root and thence through branches of the nerve. In certain regions of the body, the anterior divisions of the spinal nerves form an interlacing called "plexuses." These networks are termed the "cervical plexus" located in the neck: the "brachial plexus" in the axilla supplying the upper extremity; the "lumbar," "sacral," and "pudendal plexuses" associated with the lower extremity. The *sciatic nerve* is the longest nerve in the body (it supplies nearly all the skin of the leg, muscles of the back of the thigh, leg, and foot).

236. AUTONOMIC NERVOUS SYSTEM (fig. 118).
a. It is that part of the nervous system which controls the activity of cardiac and smooth muscle, the sweat and digestive glands, and certain of the endocrine organs. In essence, the autonomic nervous system exercises control over those reactions which are involuntary. The system is divided into a *sympathetic* and a *parasympathetic* division.

b. The cells giving rise to the sympathetic division are situated in the lateral horns of the spinal cord arising from the 1st thoracic to the 2d and 3d lumbar segments of the cord. These fibers are called "preganglionic" and leave the cord by means of the corre-

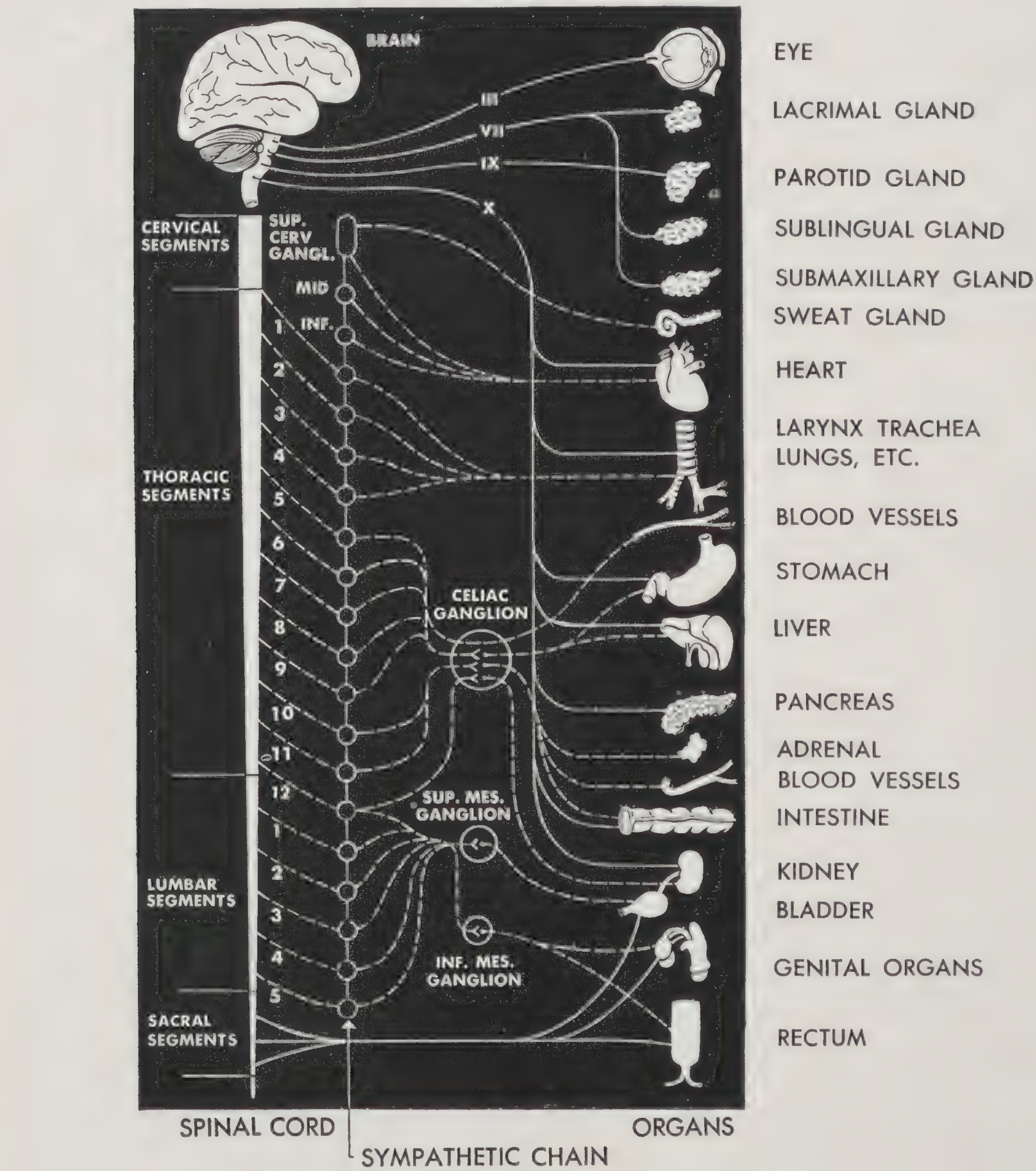


Figure 118. Autonomic nervous system.

sponding anterior nerve root through the *white ramus communicans* leading to the thoracic ganglion. Hence, sometimes this part of the system is known as the "thoracolumbar outflow." The ganglia of the sympathetic chain are connected with the spinal nerves which supply the extremities and trunk via the *gray rami communicantes.*

c. The fibers of the cranial outflow of the parasympathetic division arise from cells located in the brain. These preganglionic fibers leave in the oculomotor, facial, glossopharyngeal, and vagus nerves. The *sacral outflow* arises from the cells in the second, third, and fourth sacral segments of the spinal cord and are referred to collectively as the "pelvic nerve" (nervi erigentes).

d. The function of the sympathetic division is directed towards building up of the body against danger, attack, fear, severe muscular exercise, and the hazards of the surrounding environment; essentially, it is a "spending mechanism." It causes acceleration of the heart, dilation (opening) of the pupil of the eye, erection of the hair of the skin (goose-pimples), secretion of sweat from the sweat glands, dilation of the bronchioles in the lungs and coronary arteries to the heart; inhibition of the muscular wall of the stomach, intestine and urinary bladder, secretion of epinephrine from the medulla of suprarenal gland, and release of glycogen from the liver to form glucose for the blood. It has been found that animals may live indefinitely after complete removal of the chains of ganglia, but they must live a sheltered existence.

e. The craniosacral division has a limited action in contradistinction to that of the sympathetic. It is concerned with a "saving or conservative" reaction. Examples of this conservation are manifested by inhibition or slowing down of the heart, constriction of the pupil of the eye as a protection against intense light, activity of the digestive directed towards replenishing energy in the body, relaxing of the sphincters, and contraction of the wall of the urinary bladder.

237. SPECIAL SENSES. The specific adaptation of certain structures in the body permits reception of stimuli and their subsequent transformation into sensation. It is in the designated areas of the cerebral cortex that these stimuli are converted into conscious processes. The skin and underlying connective tissue contain receptors for pain, temperature, and touch. Other receptors are located in muscle, tendon, tongue (taste buds), nose (olfactory), retina of eye (visual), cochlea of ear (hearing), and labyrinth of ear (equilibrium). The components of a sensory mechanism consist of the sense organ or receptor, the pathway by which it is conducted into the central nervous system and the sensory centers in the central cortex. The special senses more correctly include smell, taste, sight, and hearing.

238. EYE. a. The eye is specialized for the reception of light. The optic nerve conveys the impulses to the visual area of the cerebral cortex where the sensation is made apparent.

b. The eyeball is divided into an *anterior chamber* and a *posterior chamber.* They are separated by the *crystalline lens.* The anterior chamber contains the *aqueous humor* while the posterior chamber is filled with the *vitreous humor.*

239. EAR. a. It is divisible into three parts: the *external ear,* the *middle ear,* and the *internal ear.* The external ear is known as the "auricle" or "pinna." It is composed of cartilage which is covered with skin. It projects from the side of the head and serves to collect sound vibrations of the air which are conducted by means of the external auditory canal to the middle ear.

b. The middle ear is the irregular space in the temporal bone filled with air and containing the auditory ossicles; the *incus* (anvil), *malleus* (hammer), *stapes* (stirrups). They serve to conduct vibrations from the tympanic membrane to the internal ear. The middle ear is also connected with the nasopharynx by means of the *auditory* (Eustachian) tube which serves to equalize the air pressure in the middle ear with the exterior. Another communication exists between the middle ear and the mastoid air cells.

c. The internal ear contains the receptors for hearing and equilibrium in relationship with the petrous portion of the temporal bone. Sound waves which traverse the external auditory canal to the *tympanic membrane* set up vibrations; these vibrations in turn cause the auditory bones to vibrate. The waves are transmitted to a fluid and thence to the fibers of the hair cells of the *organ of Corti.* These in turn cause impulses to travel in the auditory nerve to the *auditory* center of the cerebral cortex.

d. The semicircular canals, utricle, and saccule are concerned with equilibrium. Change in position of the head causes movement of a fluid within the canal and effects the nerve endings in contact with the hair cells.

SECTION X. ENDOCRINE SYSTEM

240. GENERAL. Within the body, in various localities, are situated the glands of *internal secretion,* sometimes referred to as the "ductless glands." The substance secreted by the glands into the blood is known as a "hormone." The substances supplied by the endocrine glands are minute in quantity since only a trace is necessary to produce an effect. They reach different parts of the body in the blood stream and influence the activity of one or another organ or tissue. The glands which produce hormones

are: thyroid, parathyroid, adrenal, pituitary, sex glands, pancreas (islet cells), intestinal glands, pineal, and thymus.

241. THYROID GLAND. a. The thyroid gland lies in anterior region of the neck below the lower border of the larynx. It consists of two lobes connected by a strip of tissues called the "isthmus."

b. The hormone secreted by the thyroid is *thyroxin;* its main function is to regulate metabolism of the body. Excess secretion of the hormone raises the metabolic rate and is known as "hyperthyroidism" and may result in exhaustion due to overstimulation. *Hypothyroidism* is due to decreased secretion and causes cretinism wherein growth is abnormal resulting in drawfism or disproportionation of the body or both. Iodine is a major constituent of thyroxin and lack of it results in glandular pathology (goiter).

242. PARATHYROID GLAND. a. The parathyroids are small round bodies, usually four in number, located in the posterior border of the lobes of the thyroid gland.

b. The hormone of the parathyroid gland is *parathormone.* It serves to regulate the calcium content of the blood and hence is related to the general metabolic state of calcium in the body. This is of particular importance since it influences the amount of calcium in certain tissues, bone formation, coagulation of blood, maintenance of normal muscular excitability, and milk production. Removal of the parathyroid glands will result in death characterized by tonic and spasmic contraction of the muscles, convulsions, elevated temperature, rapid heart beat, and profuse salivation (tetanic state).

243. ADRENAL GLAND. a. Sometimes referred to as the suprarenal glands, are two small bodies shaped like a cocked hat on top of each kidney. They consist of an outer portion called the "cortex" and an inner portion called the "medulla."

b. The hormone secreted by the medulla is called "epinephrine" (adrenalin). It causes an increase in the heart rate, increase in blood pressure, and rise in the sugar content of the blood. It enables the individual to mobilize the resources of the body during emergency periods. The hormone of the cortex is essential for life; removal of it will result in death.

244. PITUITARY GLAND. a. Frequently this gland is called the hypophysis. It is a small oval mass about the size of a pea situated in a bony depression of the middle cranial fossa known as the sella turcica. It is composed of an *anterior* and a *posterior lobe.*

b. The pituitary gland is frequently referred to as the "leader of the endocrine orchestra" in view of the fact that it has such a widespread effect upon the other glands in the body and either modifies or controls their secretions. The anterior lobe plays the master role and many different effects have been attributed to it due to the action of the:

(1) Growth hormone—which influences skeletal growth and deficiency. Overproduction of this hormone may result in abnormalities (giantism and acromegaly).

(2) Thyrotropic hormone—which influences the thyroid gland causing it to secrete.

(3) Gonadotropic hormone—which stimulates the gonads (ovary and testes).

(4) Adrenotropic hormone—which is related to growth of the adrenal gland.

(5) Lactogenic hormone—which is responsible for the growth of the mammary glands during pregnancy and for the production of milk.

(6) Diabetogenic effect—which is the relationship produced by the influence of the pituitary upon the pancreas.

(7) Parathyrotropic effect—which has an influence upon the function of the parathyroids.

(8) Pancreatropic effect—which stimulates the production of insulin from the pancreas.

c. A crude extract can be obtained from the *posterior lobe* called "pituitrin." The extract is divisible into two fractions (pitressin and pitocin). Essentially, the extract of the posterior lobe has an effect upon smooth muscle causing it to contract.

245. SEX GLANDS. The gonads (ovary in the female and testes in the male) produce hormones which stimulate growth either as a man or a woman. They also produce the cells concerned with reproduction (ova in the case of the female and spermatozoa in the case of the male).

246. PANCREAS. The islet cells of the pancreas produce a hormone called "insulin" which is essential for the oxidation of carbohydrate in the tissues. Hypofunction of the cells results in diabetes mellitus. Injection of insulin relieves the condition.

247. INTESTINAL GLANDS. The duodenum supplies a hormone called "secretin" which causes the intestinal juices to flow whenever food reaches the intestines. The liver and spleen are also believed to supply hormones to the blood.

248. PINEAL GLAND. It is a small gland located near the roof of the third ventricle of the brain. It is considered to exert an influence on the rate of growth of the entire body and the commencement of puberty.

249. THYMUS. It is a temporary organ located partly in the neck and thorax. It is large in infancy and shrinks as the individual matures. Little is known of its function.

CHAPTER 10

ROENTGENOGRAPHIC TECHNIQUE

250. GENERAL. The field of roentgenography has advanced to a stage far beyond mere projection of the outlines of the skeleton as a roentgenographic image of bones alone. Scientific roentgenography should provide for visualization not only of the contour and structure of the bones but also of the surrounding soft tissues including the outline of muscle layers and facial planes. Furthermore, positioning and alignment of the focal spot should provide for constancy in projection of the anatomical relations. No longer should one be content merely to place a part heedlessly upon a film and arrange for X-rays to pervade the part with no set plan as to projected relations and with no anticipated roentgenographic quality as an end result. The figures which follow, pertaining to positioning and roentgenography, are intended to serve as a guide. It will be noted that there are included: emphasis as to the objectives concerned with each roentgenogram; recommendations as to film size and type of film holder; precautions as to positioning of the patient and alignment of the focal-spot; and modifications which may be required because of the condition of the patient. All of these aspects are important. It is likewise important to have in mind the technical factors required to obtain suitable roentgenographic quality. The factors listed in the succeeding figures are values which have been tested repeatedly with equipment of average performance. They represent ideal values for such equipment; values which permit increments of exposure to as much as 30 to 50 percent additional milliampere-seconds or reductions of exposure to the same extent. Regardless of the latitude provided with this technique it is realized that with some equipment, these values may produce excessive densities; with other equipment they may produce under-exposure. However, it is believed that the factors listed are sufficiently reliable, in a relative manner, that whatever change may be indicated for one part, such changes will be found indicated consistently for all parts—that a common factor (that is, such as adding or subtracting uniformly 2 to 8 kvp as compared with the values listed) can be applied to this technique to make it applicable to any machine regardless of differences in wave form, meter values, tube performance, and the gamut of uncontrollable variables.

251. MODIFICATIONS. For the sake of simplicity the technical factors listed are based upon: variations of kilovoltage (depending upon basic tissue density and thickness of the part) and, constancy of the other three factors: milliamperage, time (milliampere-seconds), and distance. For most projections, the factors are based on a 30-inch focal-film distance. It is realized that for certain parts, it may be desirable to increase the focal-film distance to 36, 40, 48, or even 72 inches. In such instance, this can be accomplished merely by compensating with changes in milliampere-seconds in accordance with the factors in table XI, app. V. Likewise, alterations in detail, contrast and roentgenographic density may be accomplished by application of the principles described in paragraphs 126 through 130. The tabulation of kilovoltage values is related to the relative density of the part and the thickness of it in the particular individual. The importance of actual measurement is emphasized. It is taken for granted that additional kilovoltage will be applied in case of inflammation, fluid content, the presence of a cast, etc.; whereas, a reduction in kilovoltage (4 to 6 kvp) should be made for debilitated patients or those bedridden for a long period of time, as well as for the very young and the aged. This compilation of technique is intended as a guide for the technician who has not become fully acquainted with his apparatus. It is anticipated that modifications may be made of this general plan with listings of values which might be more pertinent to one or another installations.

252. CALCULATING FOR AN EXPOSURE. It may be necessary to accomplish roentgenography without there being any recourse to an outline of technical factors and without having any pertinent factors in mind. In such a case, a few principles can be applied whereby the requirements for one or another part and one or another individual can be calculated. This might be considered as a "reasoning technique." For simplicity's sake, it might be based on a focal-film distance of 30 inches and basic exposure of 50 milliampere-seconds, the kilovoltage may be varied in accordance with the inherent tissue density of one or another part and the thickness of the particular part as found by measurement of the individual. For instance, it is easy to realize that the density of the tissues of the hand is much less than the density of the tissues of the knee; the osseous structure in the hand constitutes about half or less of its total density. Whereas, in the knee, the osseous structure constitutes approximately 90 percent of the density. Furthermore, the compactness of the bone in the hand, is much less than that of the knee. Likewise, with other parts of the body, one might consider the relative percentage of bone versus soft tissues and, then too, the particular density of the bone. As a further example, the osseous structure of the head of the femur or of the acetabulum is much more compact than the osseous structure of the ribs. Roughly, one might make allowances for these variations of tissue density of part by utilizing a range of kilovoltages varying from 40 to 60. Having some conception of osteology and gross anatomy, it is not a difficult matter to estimate a kilovoltage value for one or another density, estimating variations in densities and varying from an allowance of 40 kvp for a hand to as much as 60 kvp for a hip; this allowance pertaining solely to the *density* of the part and serving as a starting value in the estimation of the kilovoltage required. There-

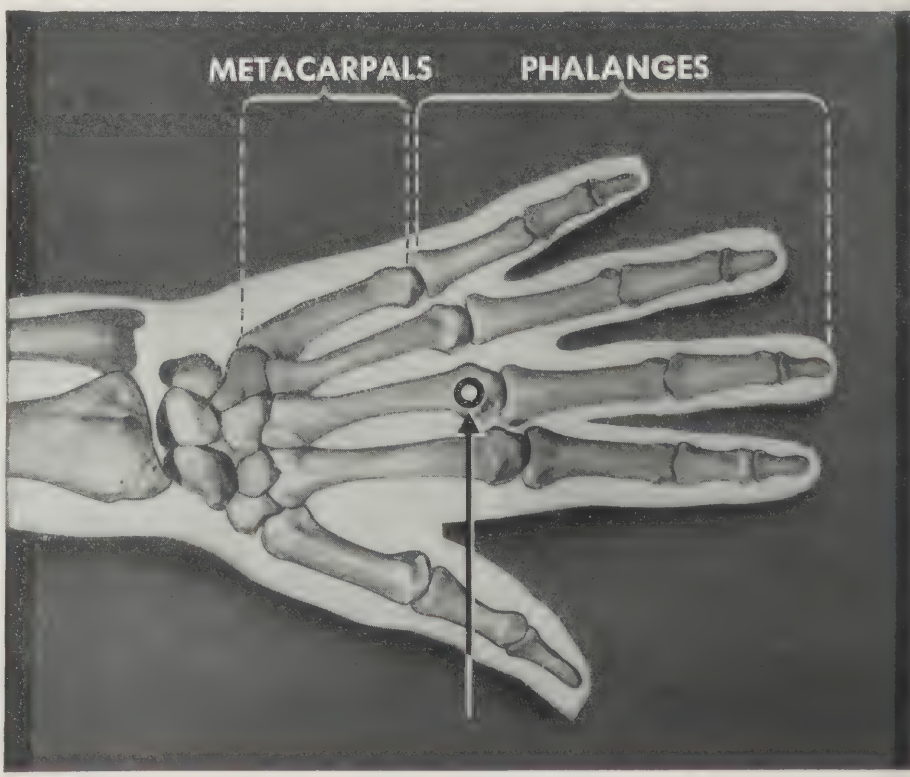
after, one may allow 2 kvp for each cm thickness. This calls for measurement of the part; a measurement to be accomplished after the patient has been positioned for the exposure. The measurement should be made through the plane to which the focal spot of the X-ray tube has been aligned. With relatively thin parts, parts of 10 cm or less, this system is very simple. For instance, let us consider a hand, measuring 3 cm in thickness. The technical factors would be: 30-inch focal-film distance, the film being placed in a cardboard holder, the milliamperage-second value being 50, the kilovoltage factor being 40 (for the tissue density of the part) plus 6 kvp (allowing 2 kvp for cm thickness)—the kilovoltage required would be 46. Applying the values to the formula:

$$\text{base value} + (\text{cm thickness} \times 2) = \text{kvp required}$$
$$40 + (3 \times 2) = 46 \text{ kvp}$$

or let us consider a knee measuring 10 cm in thickness. It is reasonable to estimate a base value requirement of 54 kvp. To this, there should be added 20 kvp (10 cm thickness x 2)—making a total of 74 kvp as the roentgenographic setting. With parts of greater thickness, these calculations may become more complicated. It may be necessary to convert a roentgenographic density of a calculated kilovoltage value into comparable densities as produced by milliampere-second compensation. For instance, one might consider a hip measuring 20 cm. Allowing 60 kvp as an estimated base value (for the density of this part) plus 40 kvp for the thickness of it, there would be indicated a requirement of 100 kvp. It is not advisable to utilize such a high kilovoltage for a part such as that of the hip for there is produced thereby an excessive amount of secondary radiation and, therefore, excessive fogging of the X-ray film. Furthermore, very few X-ray machines would tolerate 100 kvp with any appreciable milliamperage load. One may decide to reduce this kilovoltage value, perhaps to 72. This can be accomplished by increasing the milliampere-second value fivefold—that is, because of dropping 28 kvp. (See par. 136.) Thus, the milliampere-second value should be increased to 10 x 50 MaS or to 500 MaS. Such would be the milliampere-second requirement so far as blackening of the film emulsion by X-radiation alone. If intensifying screens are used (as would be recommended for a part of this thickness) then this milliampere-second value would have to be reduced in accordance with the intensification factor of the intensifying screens for 72 kvp. (See par. 123d.) With medium speed intensifying screens this factor has been found to average 25. (See fig. 71b.) Therefore, the 500 milliampere-seconds, above estimated, would be reduced to 500 divided by 25—that is, to 20 milliampere-seconds. It would seem advisable to make use of a grid in order to absorb some of the secondary radiation produced because of the density and thickness of the hip tissues. There would then be required additional exposure, preferably as produced by increased milliampere-seconds. With a 5 to 1 ratio wafer type of grid (such as the U. S. Army wafer grid) for the average thickness of part, the milliampere-second value should merely be doubled* over that which might be required without the use of the grid. With a 5 to 1 ratio, moving type of grid, this value would have to be tripled, for the average case. Considering the use of the Army wafer grid, the above calculated 20 milliampere-seconds would have to be increased to 2 x 20 milliampere-seconds. Supposing that in addition to making use of a grid, it seemed practical to limit the field exposed by the primary radiation, in order to reduce even further the secondary radiation. This could be accomplished with the use of a lead diaphragm, positioned beneath the exit portal of the X-ray tube housing; it could be accomplished with the use of a lead diaphragm positioned over the part, or it might be accomplished with the use of a cone or an extension cylinder. With any one of these, it would be necessary to further increase the milliampere-seconds factor. The amount of such increase would depend upon the diameter of the effective portal, considering the exit beam through the tissues. Roughly, the use of diaphragms or cones require compensating by additional milliampere-seconds exposures (increased by as much as 40 percent added to that which might be used without them). For instance, in the case of the problem cited above, if a very small effective cone were used, it would then be necessary to increase the milliampere-second value by adding 40 percent of the milliampere-seconds already accounted for—that is, by multiplying 40 milliampere-seconds by the factor 1.4—thereby calling for 56 milliampere-seconds. Thus, for this particular hip, it would have been calculated that with the use of medium speed intensifying screens, the use of the U. S. Army wafer grid and the use of a small cone, that the following factors would be required: distance 30 inches; kilovoltage 72; milliampere-seconds 56 (or as near to that value as the milliammeter and the timer might permit). This outline is not presented with the belief that it should be applied for each and every exposure, time after time. It is realized that in any well established clinic, eventually there is set up a listing of factors which provide for the quality of roentgenography desired by roentgenologists concerned. This is as it should be for with such arrangements, roentgenography is accomplished more rapidly. In short, the above described system is presented merely for assisting one when the selection of exposure factors is not easily available; when the factors are not in mind. This system is offered as a basis for developing a listing of more ideal factors.

* This seems practicable when using U. S. Army wafer grid regardless of variations in tissue density and in kilovoltage selected.

Fig. 119.—HAND, POSTERO-ANTERIOR



ANATOMICAL: Metacarpals, phalanges and carpals, semi-lateral thumb and soft tissue.

FILM: 8 x 10 inch, lengthwise.

POSITION: Ulna surface in contact with film; hand at 45° angle; phalanges in extension and head of the third metacarpal to center of film.

FOCAL SPOT: Align to head of the third metacarpal to center of film.

PRECAUTION: ELBOW ON TABLE, maximum separation of fingers.

ADDITIONAL: Sandbag immobilization of forearm. Non-opaque support (cork) may be used under head of second metacarpal.

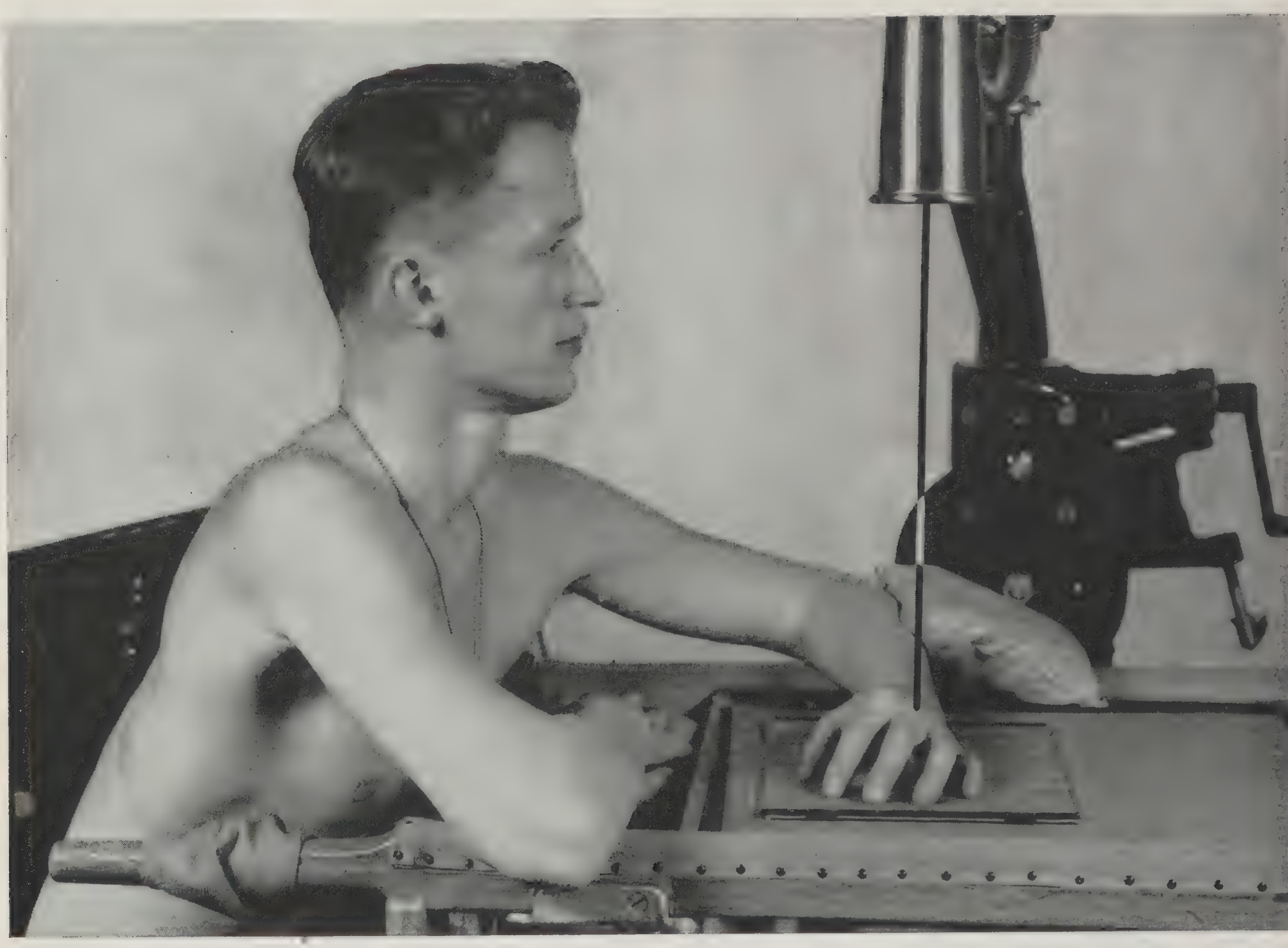
VARIATIONS: For finger tip or single articulation, dental or occlusal film may be used.

DISTANCE: 30″ — Measure through head of 3rd metacarpal

CMS. THICKNESS		2	3	4	5	6
VARIABLE KVP	with cardboard holders	44	46	48	50	52
	with medium screens					
	with Army wafer grid					
MA - SEC				50		

AUXILIARIES: CONE:

Fig. 120.—HAND, OBLIQUE



ANATOMICAL: Metacarpals, phalanges and carpals; semi-lateral thumb and soft tissues.

FILM: 8 x 10 inch, lengthwise.

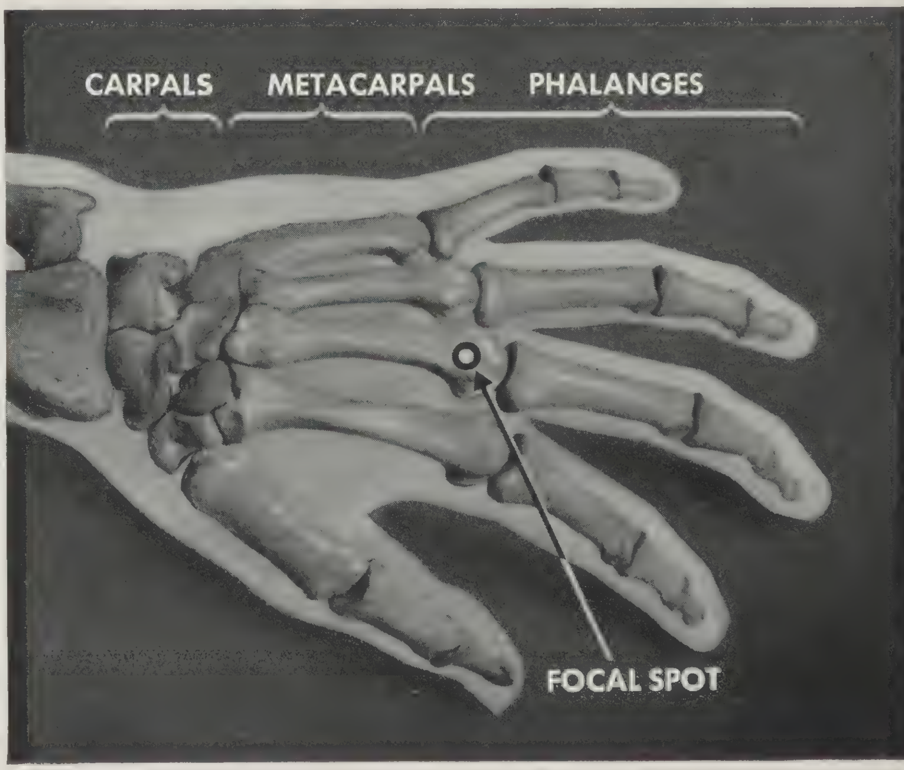
POSITION: Hand flat, head of 3rd metacarpal to center of film.

FOCAL SPOT: Align to head of 3rd metacarpal to center of film.

PRECAUTION: Elbow on table, fingers flat and separated.

ADDITIONAL: Sandbag immobilization of forearm.

VARIATIONS: The lateral projection of the thumb is made by clenching fingers into palm, thus rotating thumb into true lateral position. For tip of finger or single articulation, etc., a dental film may be used.

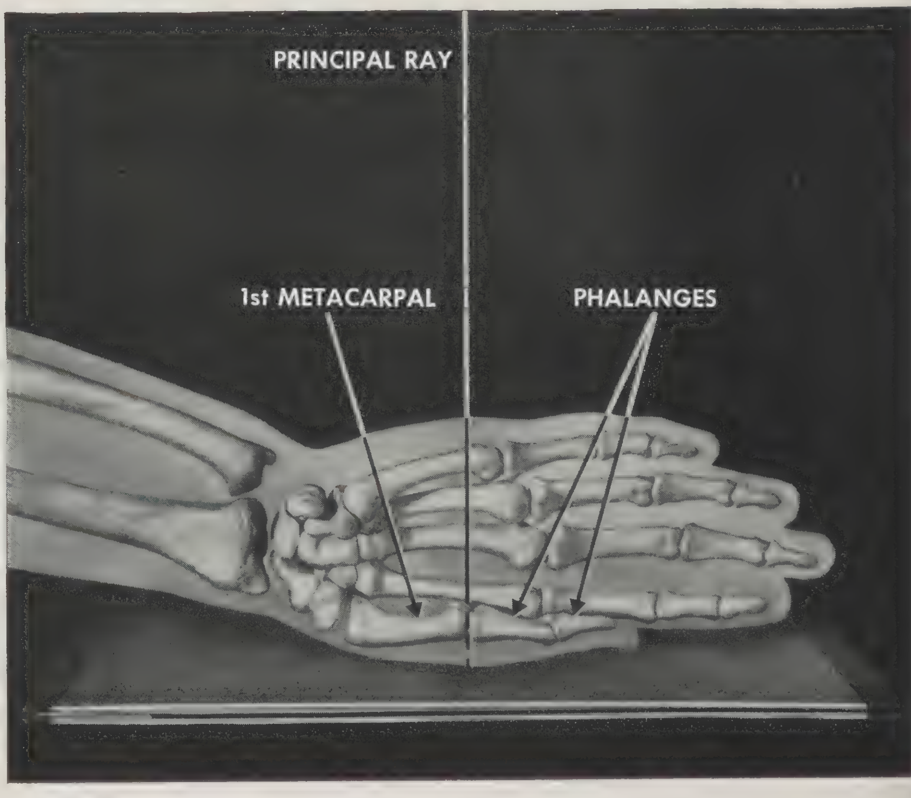


DISTANCE: 30″ — Measure through head of 3rd metacarpal

CMS. THICKNESS		2	3	4	5	6
VARIABLE KVP	with cardboard holders	48	50	52	54	56
	with medium screens					
	with Army wafer grid					
MA - SEC				50		

AUXILIARIES: CONE.

Fig. 121.—THUMB, ANTEROPOSTERIOR



ANATOMICAL: Phalanges, metacarpal and soft tissues.

FILM: 8 x 10 inch, lengthwise.

POSITION: Forearm in internal rotation, with dorsum of thumb and radial side of index finger in contact with film, palm at 90° angle.

FOCAL SPOT: Align to 1st metacarpophalangeal articulation.

PRECAUTION: Forearm slightly elevated on sandbag.

ADDITIONAL: Immobilization of forearm; cone advisable.

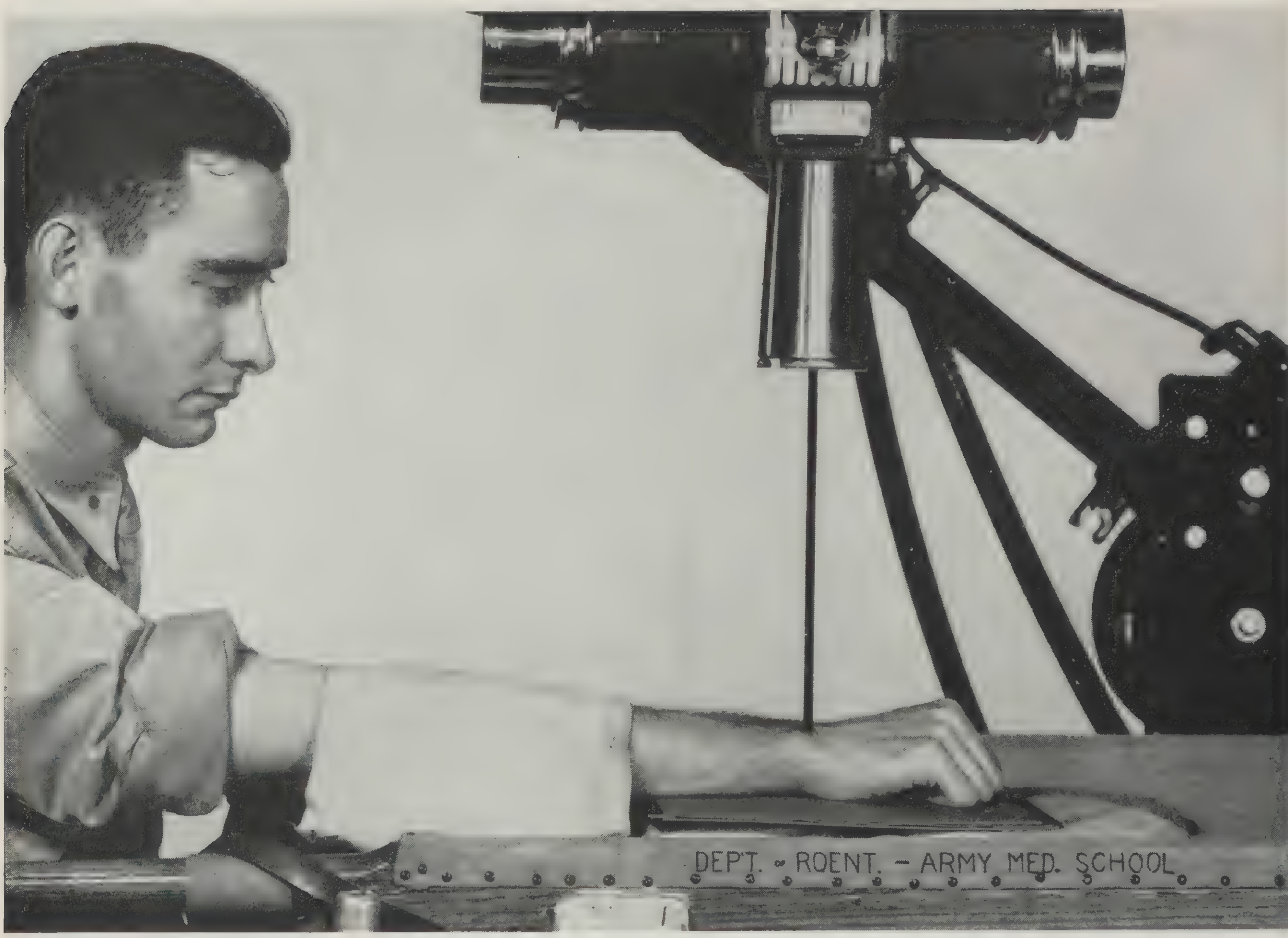
VARIATIONS: Use P-A projection if patient is unable to rotate forearm. Ulnar side on film, palm at 90° angle, thumb adducted to horizontal plane and supported on non-opaque pad (true lateral view of hand). P-A hand accomplishes lateral thumb. Single film accommodates multiple projections.

DISTANCE: 30″ Measure through metacarpophalangeal joint

CMS. THICKNESS	2	3	4	5	6
VARIABLE KVP with cardboard holders	44	46	48	50	52
VARIABLE KVP with medium screens	.	.	.	.	.
VARIABLE KVP with Army wafer grid	.	.	.	.	.
MA - SEC			50		

AUXILIARIES: CONE.

Fig. 122.—WRIST, POSTERO-ANTERIOR



ANATOMICAL: Distal radius and ulna, carpals, metacarpals and soft tissues.

FILM: 8 x 10 inch, lengthwise.

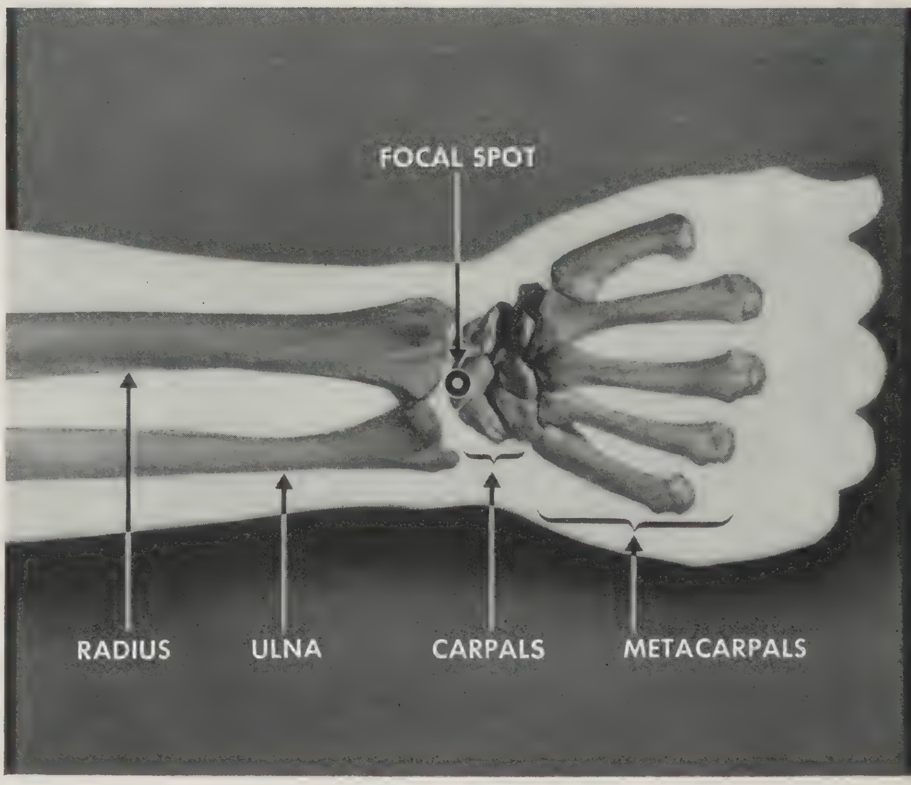
POSITION: Tips of styloid processes at midlength of film.

FOCAL SPOT: Align to point midway between tips of styloid processes to center of film.

PRECAUTION: Elbow on table, fist clenched.

ADDITIONAL: Sandbag immobilization of forearm.

VARIATIONS: For carpal bones and joints anteroposterior, with dorsum closer to film, is advisable. Navicular best visualized in postero-anterior projection with hand in ulna deviation, or by oblique elevation of hand 20° (i.e., plane of clenched fist).

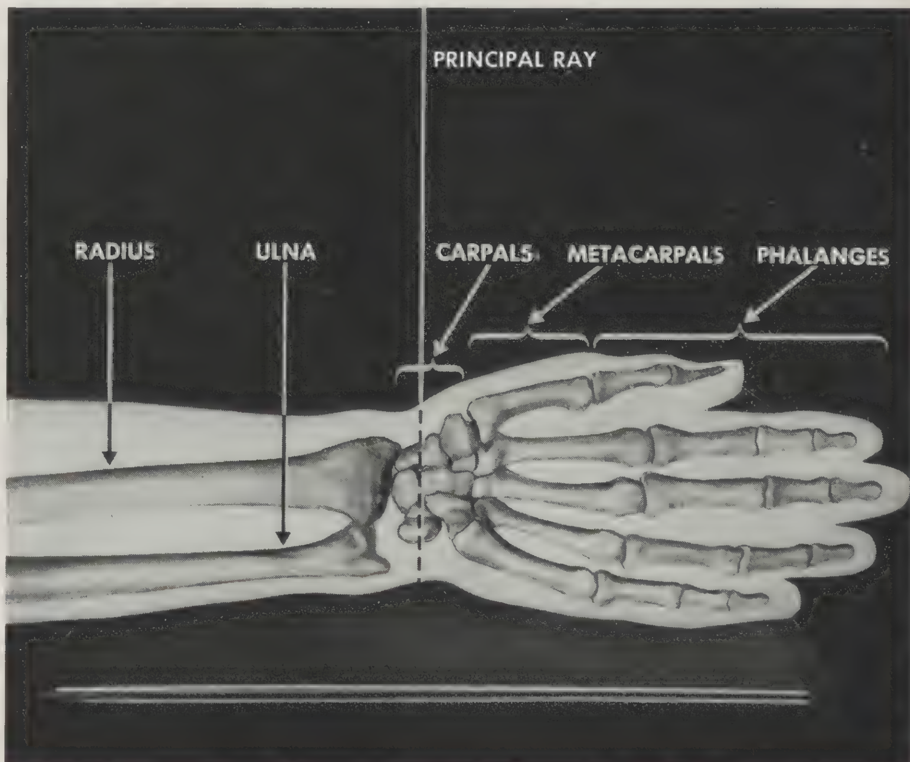


DISTANCE: 30″ — Measure through tips of styloid processes

CMS. THICKNESS		2	3	4	5	6	7	8
VARIABLE KVP	with cardboard holders	54	56	58	60	62	64	66
	with medium screens							
	with Army wafer grid							
MA - SEC					50			

AUXILIARIES: CONE.

Fig. 123.—WRIST, LATERAL



ANATOMICAL: Radius, ulna, carpals and metacarpals.

FILM: 8 x 10 inch, lengthwise.

POSITION: Ulnar styloid 1 cm. proximal to center of film; slight supination of forearm.

FOCAL SPOT: Align to center of film (1 cm. distal to radial styloid).

PRECAUTIONS: Elbow on table, styloids superimposed.

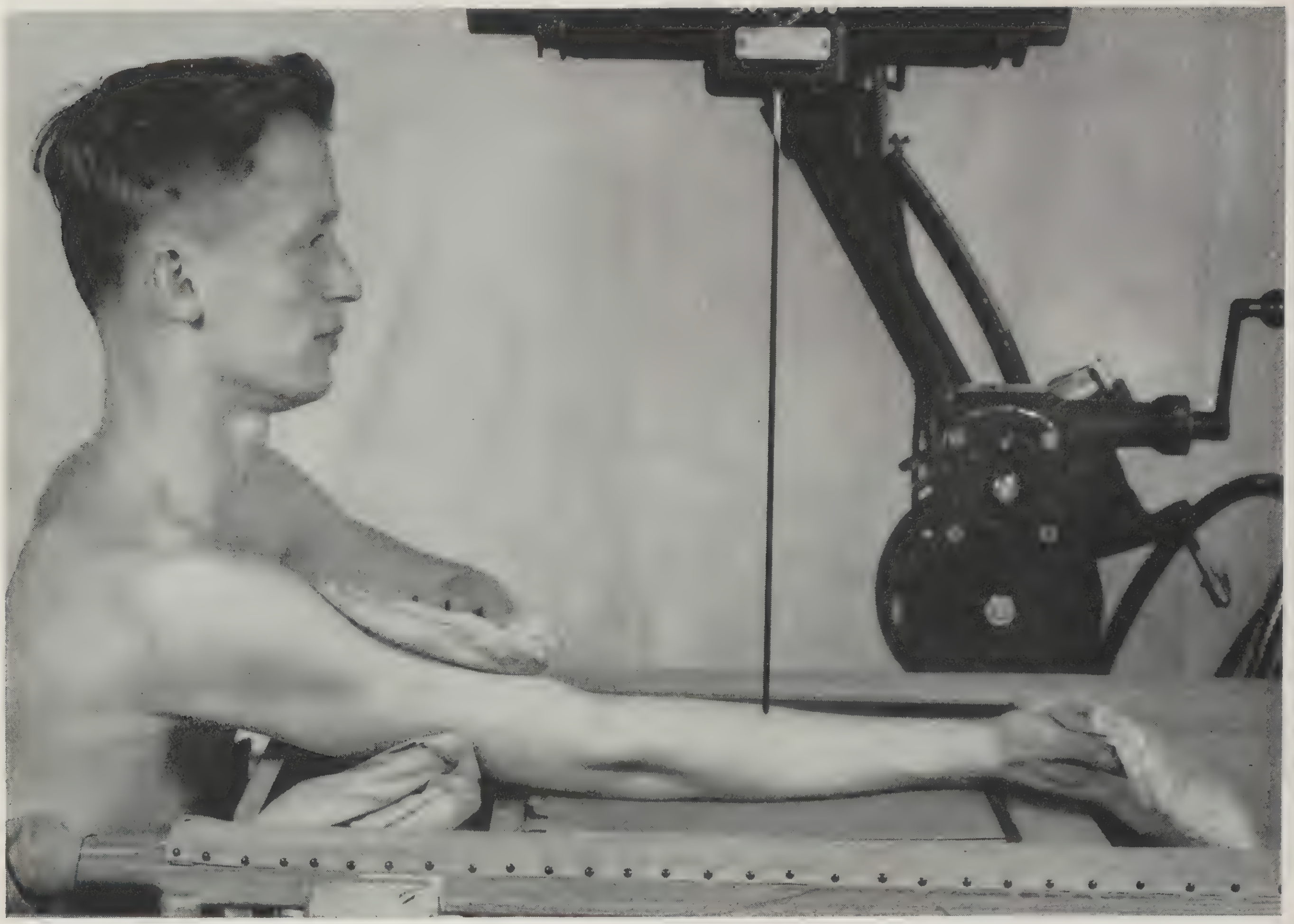
ADDITIONAL: Fingers extended, immobilize hand and forearm.

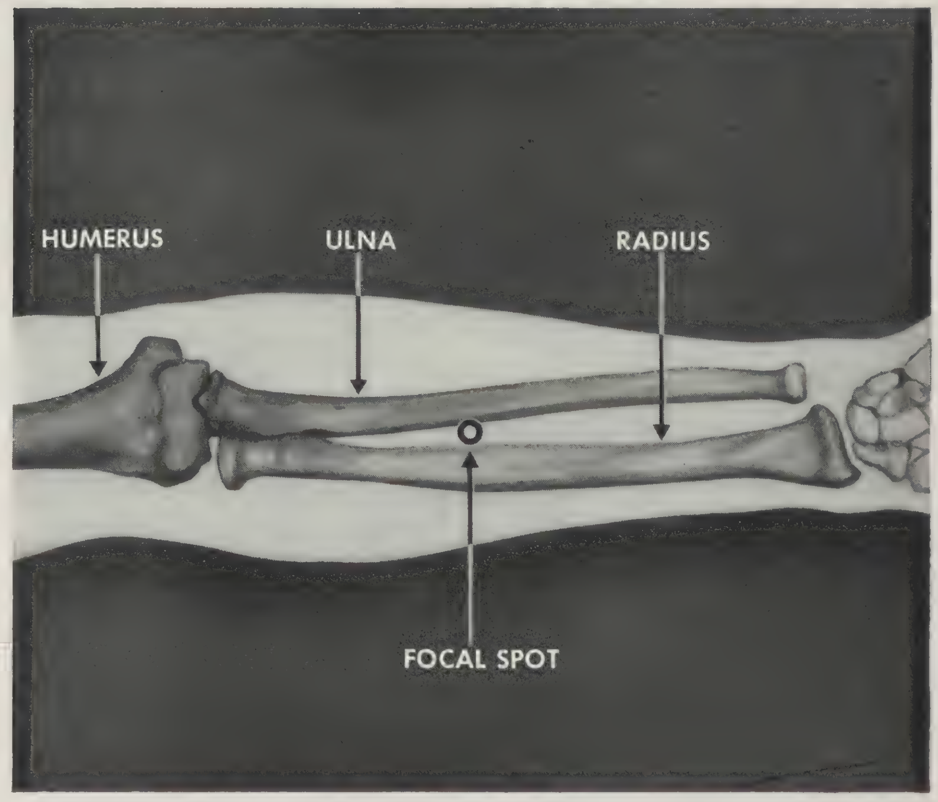
NOTE: If wrist is in cast or splint, same relations should be obtained by adjustment of film and tube.

DISTANCE: 30″	Measure through tips of styloid processes							
CMS. THICKNESS		3	4	5	6	7	8	9
VARIABLE KVP	with cardboard holders	58	60	62	64	66	68	70
	with medium screens	.	.	.	.	.	.	.
	with Army wafer grid	.	.	.	.	.	.	.
MA - SEC					50			

AUXILIARIES: CONE.

Fig. 124.—FOREARM ANTEROPOSTERIOR





ANATOMICAL: Radius, ulna and soft tissues.

FILM: 10 x 12 inch, lengthwise.

POSITION: Arm extended, palm upward, dorsum of forearm closest to joint nearer site of injury 3 to 5 cm. from end of film.

FOCAL SPOT: Align to center of film.

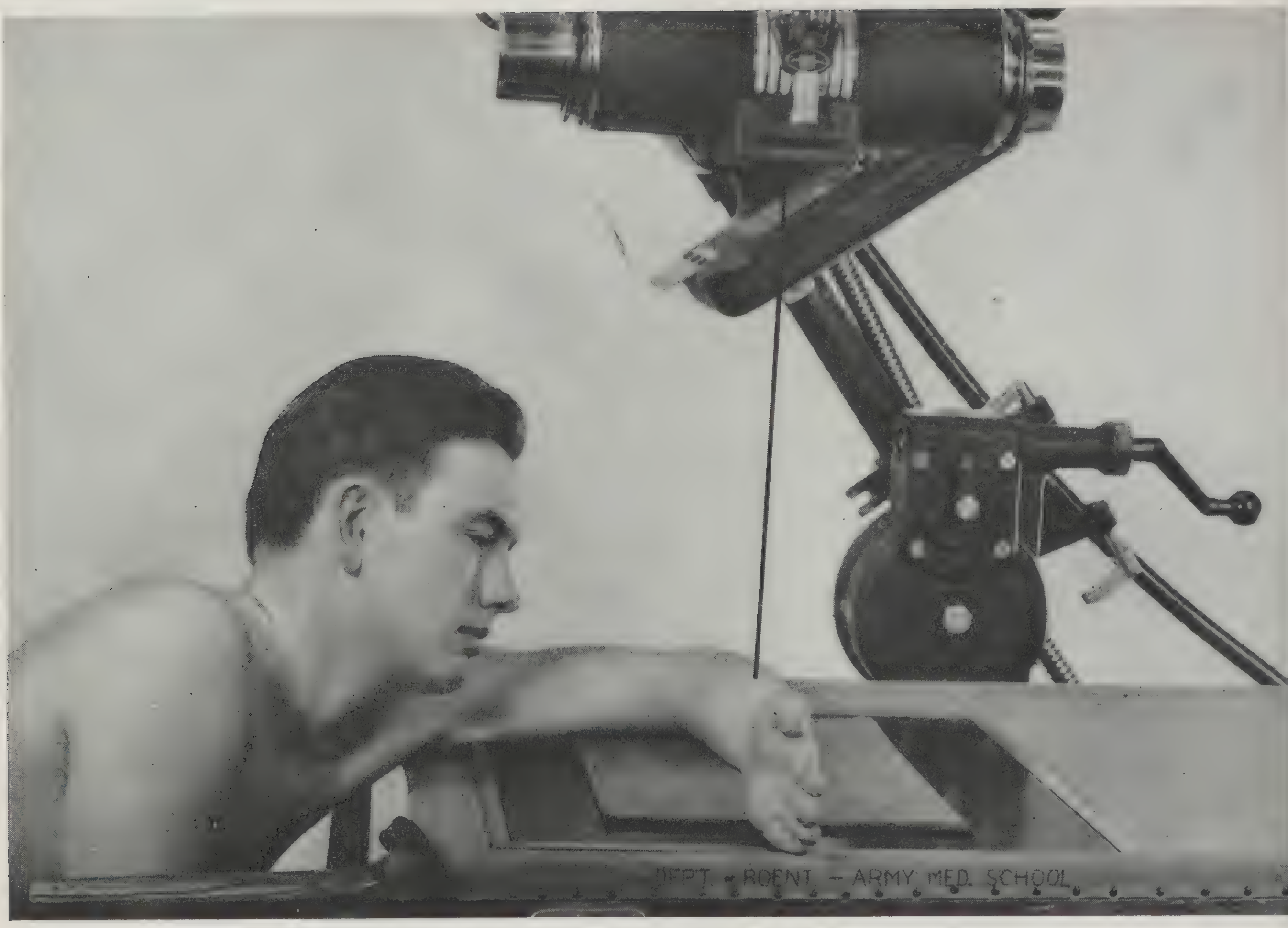
PRECAUTION: Immobilization by sandbags over palm and across arm.

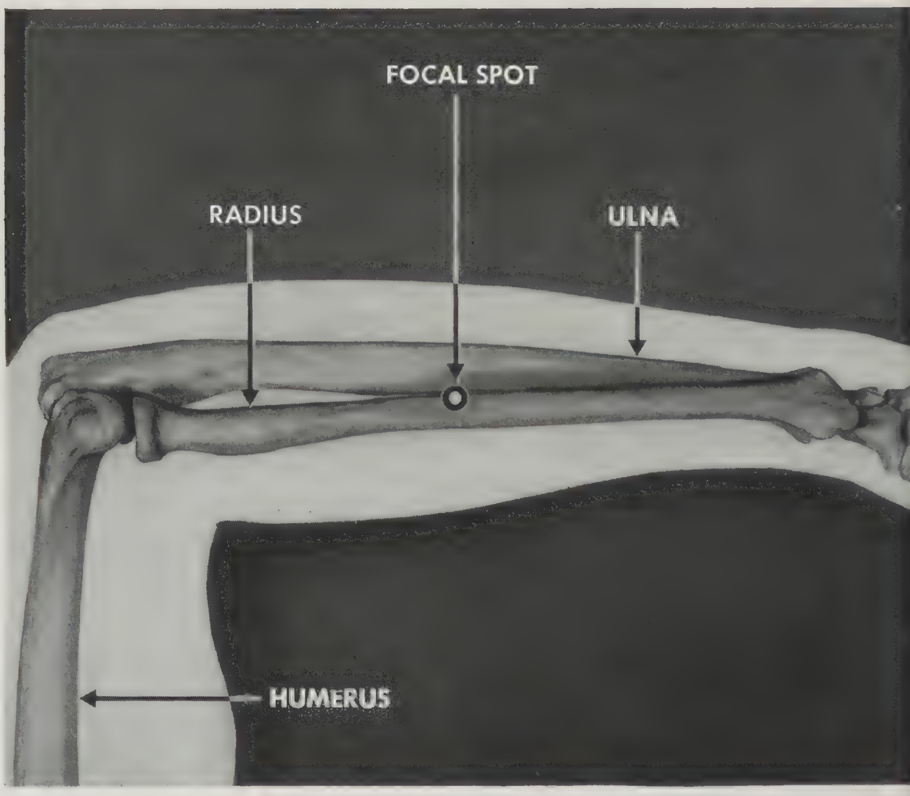
DISTANCE: 30″ — Measure through midlength of forearm

CMS. THICKNESS		3	4	5	6	7	8	9	10
VARIABLE KVP	with cardboard holders	60	62	64	66	68	70	72	74
	with medium screens	.	.	.	.	.	.	.	.
	with Army wafer grid	.	.	.	.	.	.	.	.
MA - SEC.		50							

AUXILIARIES: CONE (10 x 12″ with film coverage).

Fig. 125.—FOREARM, LATERAL





ANATOMICAL: Radius, ulna and soft tissues.

FILM: 10 x 12 inch, lengthwise.

POSITION: Shoulder at level of table top (patient seated low); elbow flexed 90°; supinate hand 5° from the vertical plane (to superimpose styloids of ulna and radius).

FOCAL SPOT: Align to center of film.

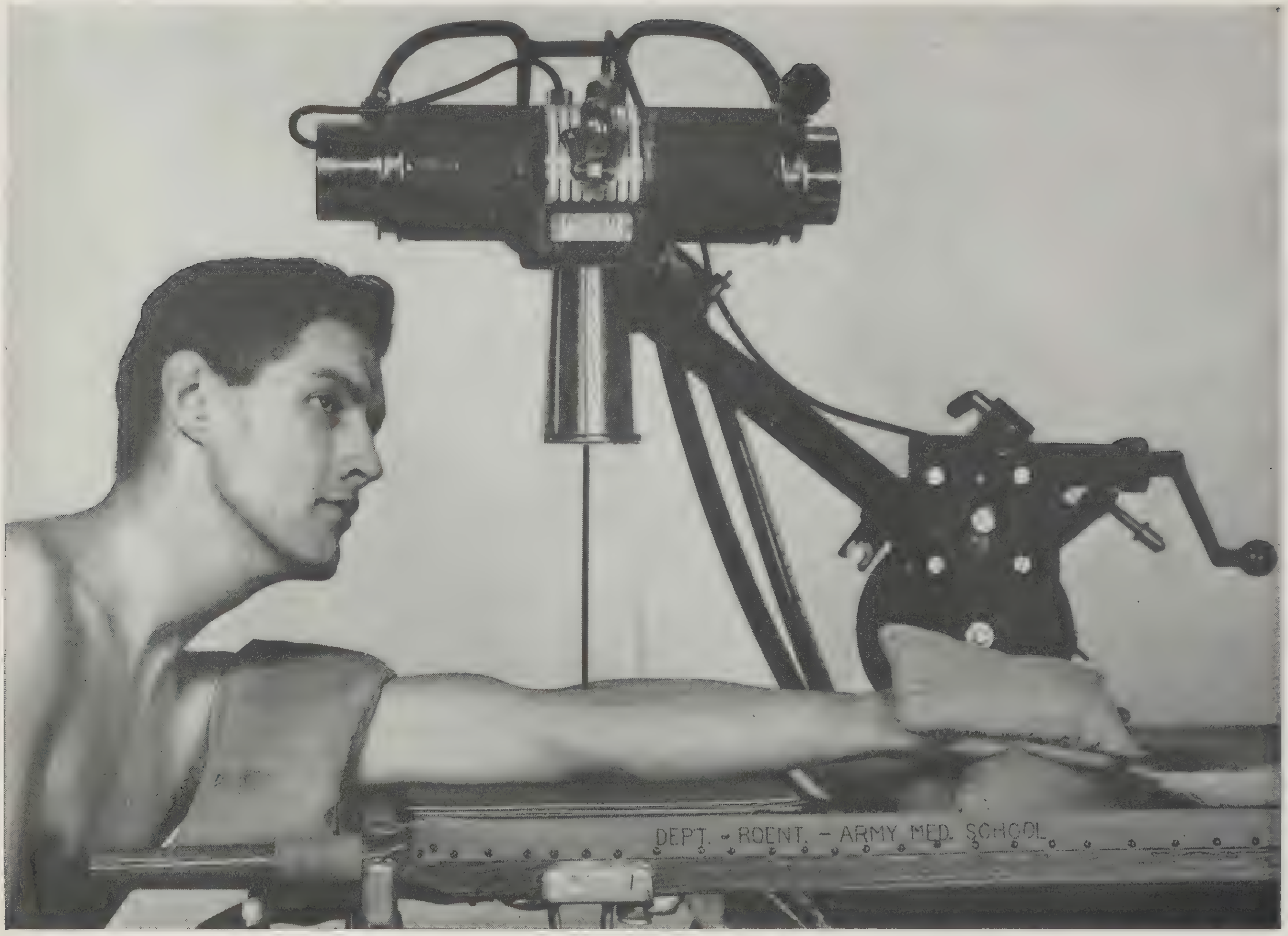
PRECAUTION: Immobilization by sandbags supporting hand and across arm.

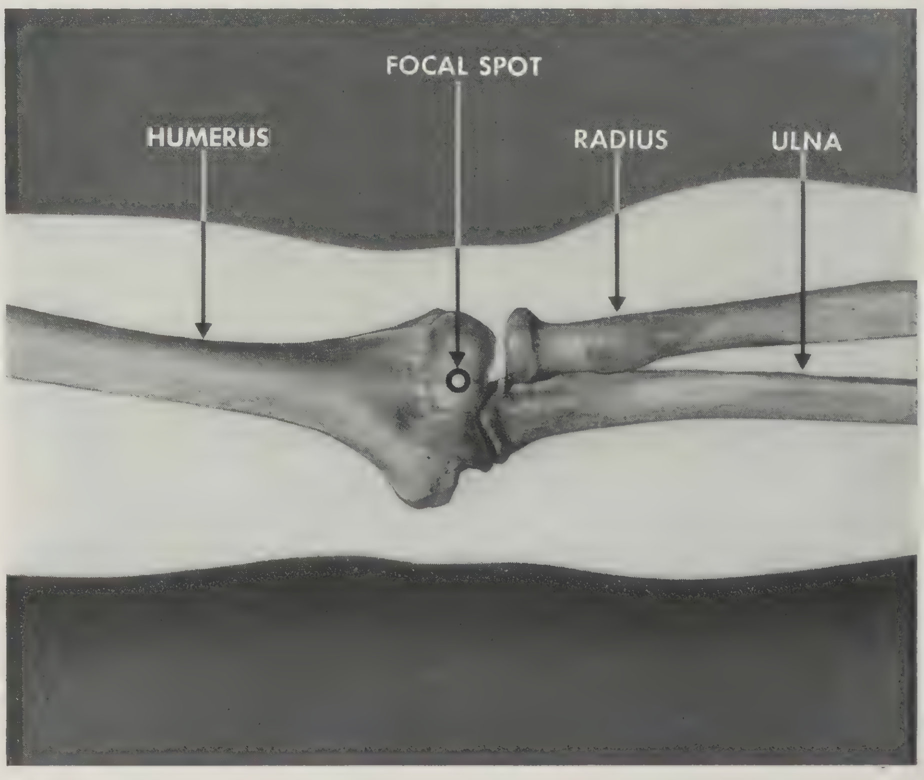
DISTANCE: 30″ Measure through midlength of forearm, laterally

CMS. THICKNESS	3	4	5	6	7	8	9	10
VARIABLE KVP with cardboard holders	60	62	64	66	68	70	72	74
VARIABLE KVP with medium screens	.	.	.	.	.	.	.	.
VARIABLE KVP with Army wafer grid	.	.	.	.	.	.	.	.
MA - SEC	50							

AUXILIARIES: CONE (10 x 12″ with film coverage).

Fig. 126.—ELBOW, ANTEROPOSTERIOR





ANATOMICAL: Humerus, radius, ulna and soft tissues.

FILM: 8 x 10 inch, lengthwise.

POSITION: Elbow fully extended, dorsum of arm and forearm closest to film; epicondyles in plane parallel to film and 2 cm. proximal to midlength of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Shoulder level with elbow, palm up.

ADDITIONAL: Immobilization by sandbags across arm and hand.

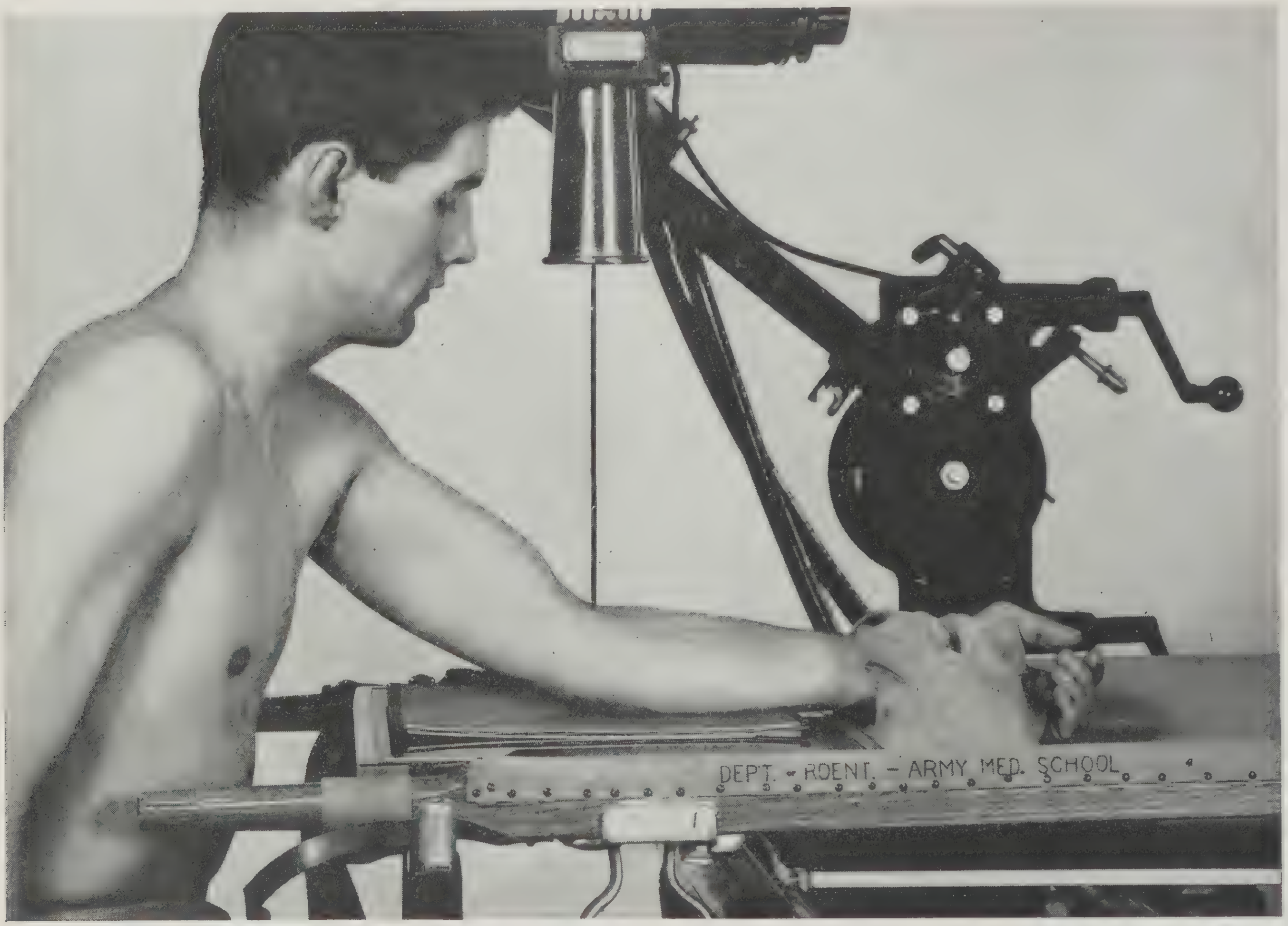
NOTE: If this positioning is impossible, accomplish upper forearm and lower arm studies.

DISTANCE: 30″ — Measure through plane of epicondyles

CMS. THICKNESS		4	5	6	7	8	9	10
VARIABLE KVP	with cardboard holders	64	66	68	70	72	74	76
	with medium screens							
	with Army wafer grid							
MA - SEC					50			

AUXILIARIES: CONE.

Fig. 127.—ELBOW, UPPER FOREARM, ANTEROPOSTERIOR (partial flexion)



ANATOMICAL: Upper extremities of radius and ulna, elbow joint and soft tissues.

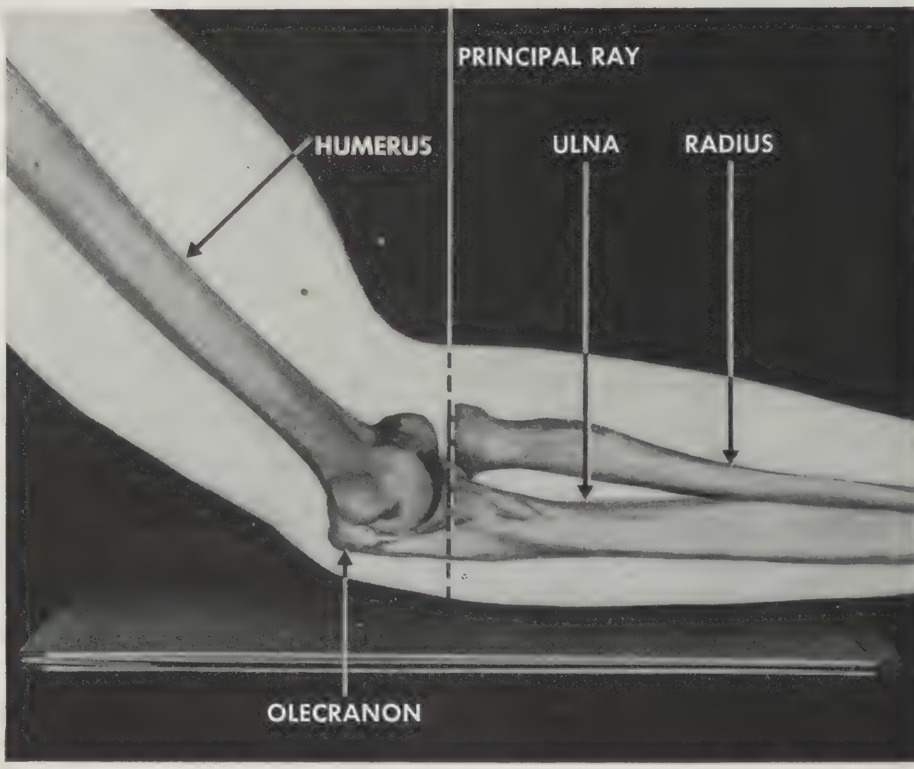
FILM: 8 x 10 inch, lengthwise.

POSITION: Forearm in contact with holder, palm upward, epicondyles 2 cm. proximal to midlength of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Immobilization with sandbags.

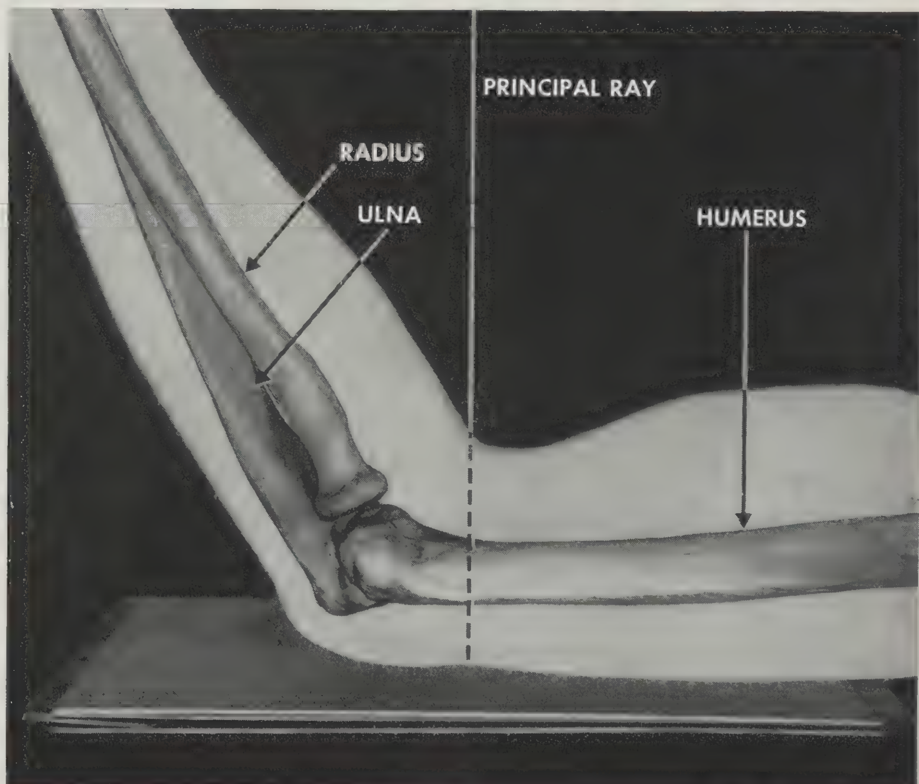
NOTE: Degree of flexion will vary with injury, position should be adjusted accordingly to visualize the articular portions of radius and ulna. Marked flexion may require angulation of principal ray toward the arm.



DISTANCE: 30″		Measure through plane of coronoid						
CMS. THICKNESS		4	5	6	7	8	9	10
VARIABLE KVP	with cardboard holders	64	66	68	70	72	74	76
	with medium screens							
	with Army wafer grid							
MA - SEC					50			

AUXILIARIES: CONE.

Fig. 128.—ELBOW, LOWER ARM, ANTEROPOSTERIOR (partial flexion)



ANATOMICAL: Lower portion of humerus, elbow joint and soft tissues.

FILM: 8 x 10 inch, lengthwise.

POSITION: Internal epicondyle 5 cm. distal to midlength of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Forearm supinated and supported and immobilized by sandbags.

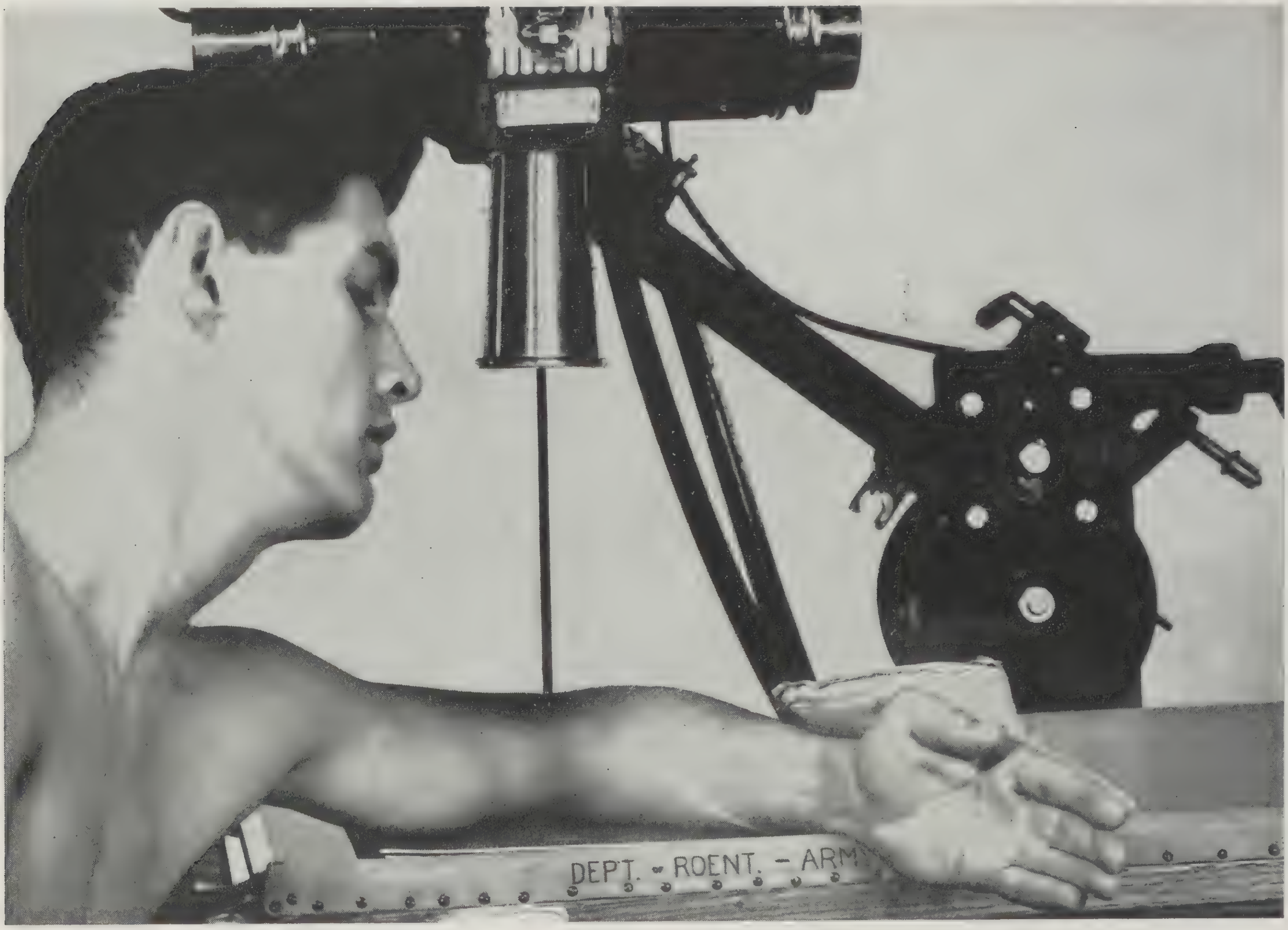
NOTE: This projection supplements the preceding projection; degree of flexion will vary with the injury; marked flexion may require angulation of principal ray toward wrist.

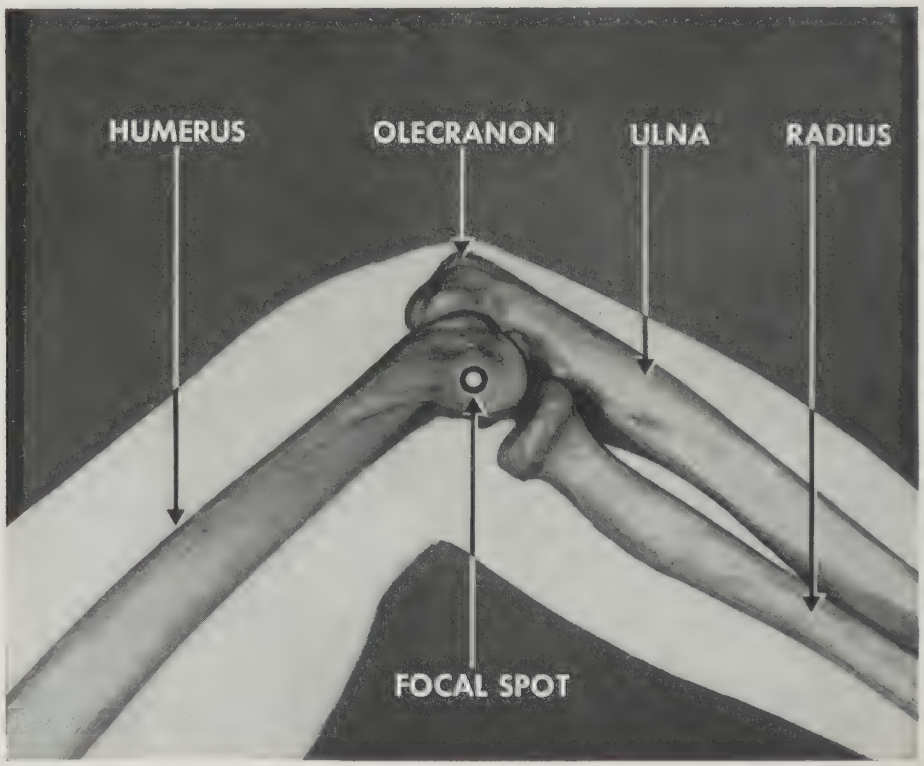
DISTANCE: 30″ — Measure through distal portion of arm

CMS. THICKNESS		4	5	6	7	8	9	10	11	12
VARIABLE KVP	with cardboard holders	64	66	68	70	72	74	76		
	with medium screens								78	80
	with Army wafer grid									
MA - SEC		50							2	

AUXILIARIES: CONE.

Fig. 129.—ELBOW, LATERAL





ANATOMICAL: Humerus, radius, ulna and soft tissues.

FILM: 8 x 10 inch, lengthwise.

POSITION: Arm and forearm on table, medial epicondyle at center of film, 45° flexion of forearm.

FOCAL SPOT: Align to 2 cm. distal to tip of lateral epicondyle.

PRECAUTION: Shoulder on level with elbow, forearm lateral with thumb and hand vertical.

ADDITIONAL: Sandbag immobilization of arm and forearm.

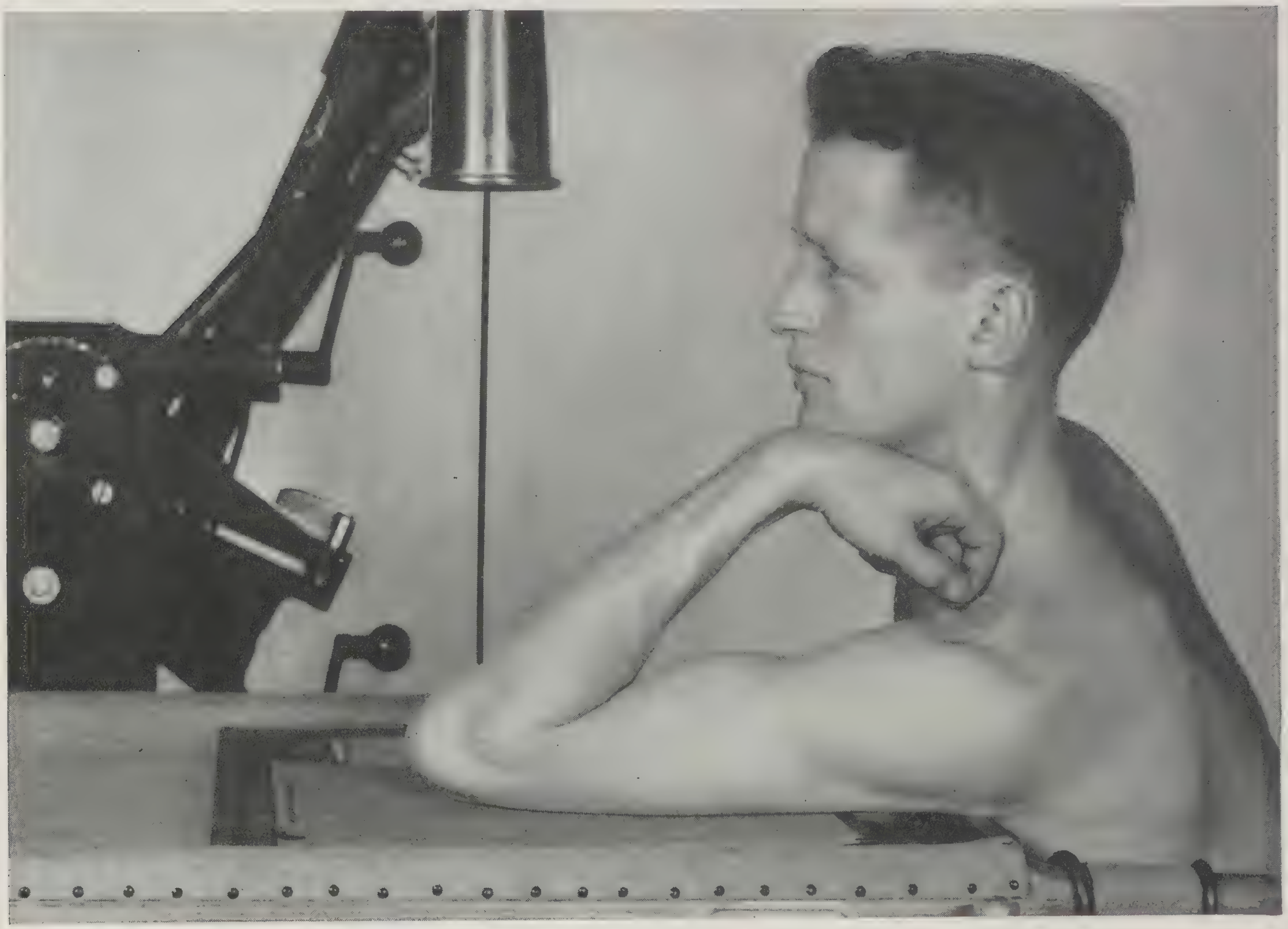
VARIATION: With the elbow maintained in the above position, various views of the head of the radius may be obtained by rotating the hand.

DISTANCE: 30″ — Measure through plane of epicondyles

CMS. THICKNESS		4	5	6	7	8	9	10
VARIABLE KVP	with cardboard holders	64	66	68	70	72	74	76
	with medium screens	.	.	.	.	.	.	.
	with Army wafer grid	.	.	.	.	.	.	.
MA - SEC					50			

AUXILIARIES: CONE.

Fig. 130.—ELBOW ANTEROPOSTERIOR (hyperflexed)



ANATOMICAL: Lower end of humerus.

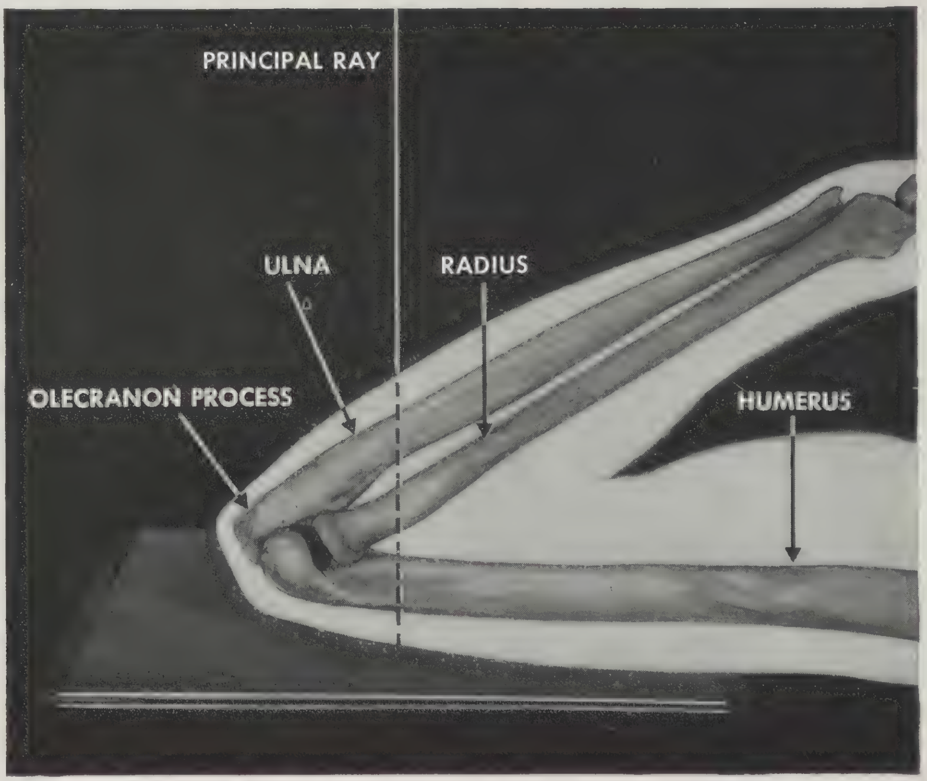
FILM: 8 x 10 inch, lengthwise.

POSITION: Posterior surface of arm resting on holder, tip of olecranon 5 cm. distal to center of film.

FOCAL SPOT: Align to point 5 cm. proximal to tip of olecranon.

PRECAUTION: Forearm directly above arm, palm facing shoulder.

NOTE: This position is of value especially for examination of an elbow immobilized in Jones position. An alternative view is made by angling principal ray 30° toward shoulder, when less distortion of radius and ulna is desired.

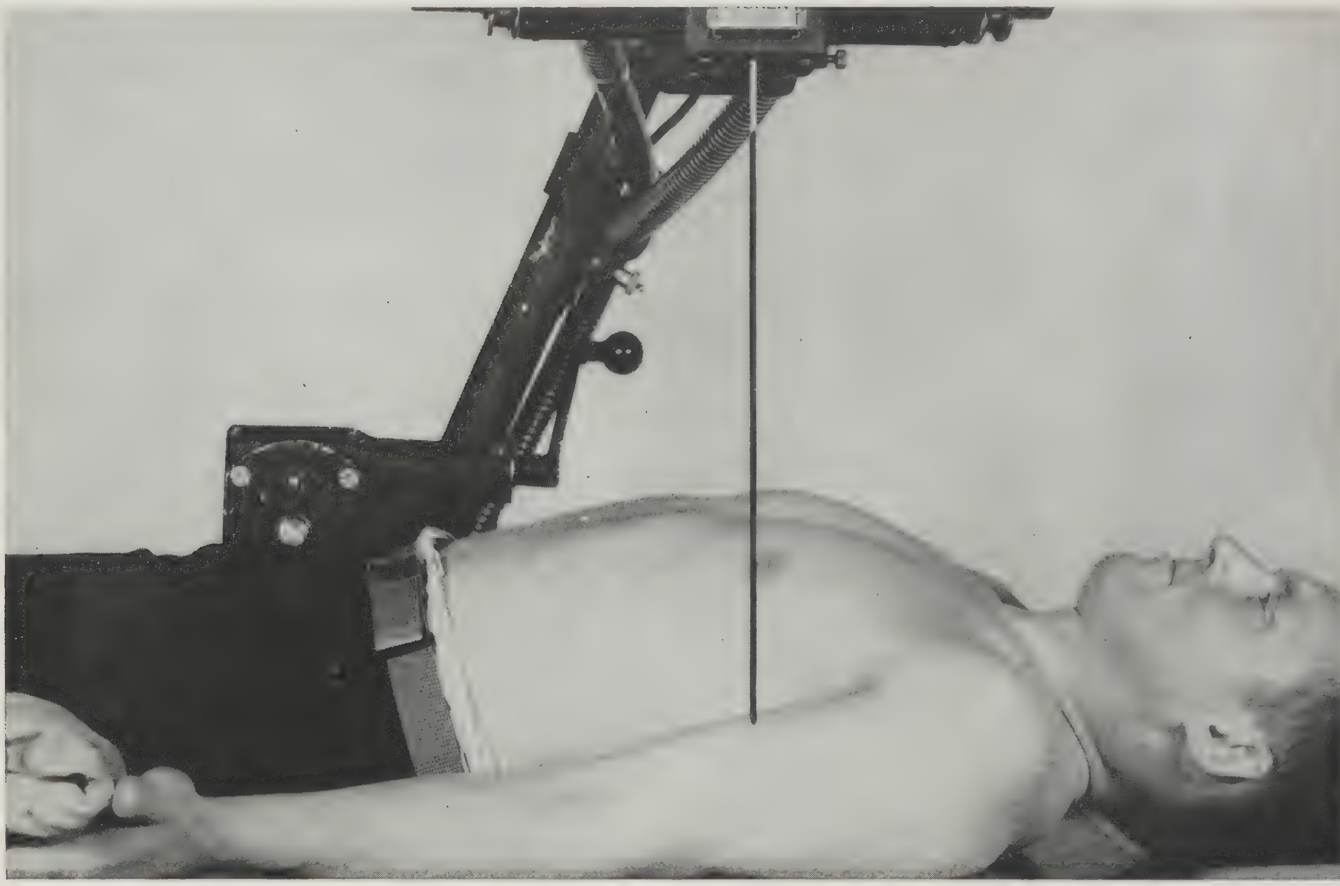


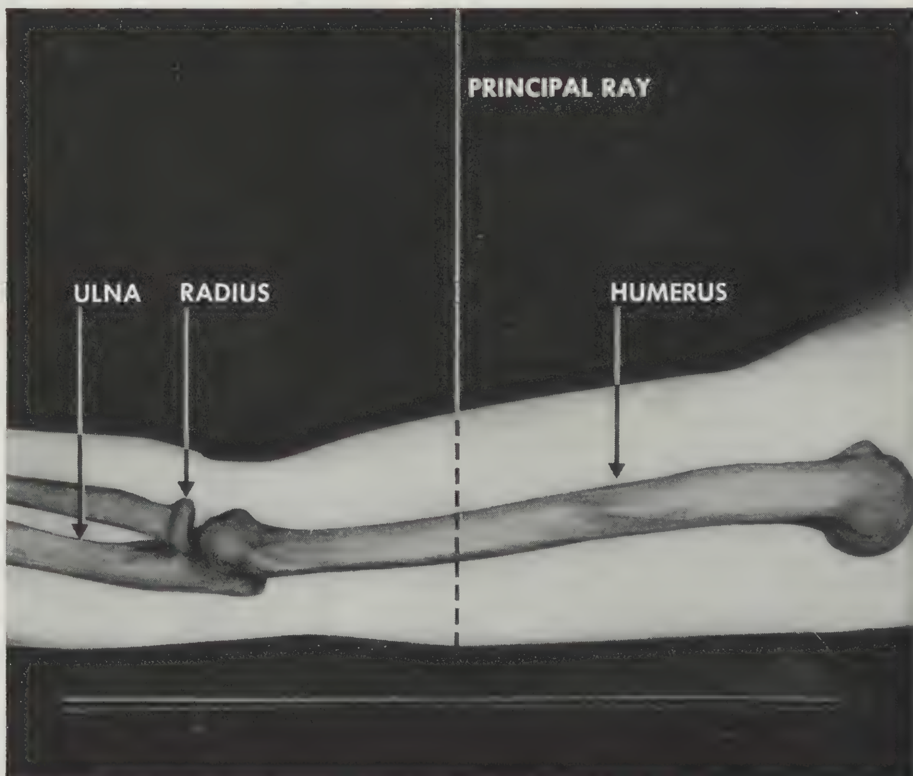
DISTANCE: 30″ — Measure through vertical plane, 5 cms. from tip of elbow.

CMS. THICKNESS		6	7	8	9	10	11	12	13	14	15	16
VARIABLE KVP	with cardboard holders	74	76	78	80	82						
	with medium screens						74	76	78			
	with Army wafer grid									80	82	84
MA - SEC				50				4			8	

AUXILIARIES: CONE.

Fig. 131.—ARM (humerus), ANTEROPOSTERIOR





ANATOMICAL: Humerus and soft tissue.

FILM: 10 x 12 inch, lengthwise.

POSITION: Arm placed to include joint nearer site of injury—5 cm. from film border.

FOCAL SPOT: Align to center of film.

PRECAUTION: Hand supinated, immobilized. Elevation of opposite shoulder to insure minimal part-film distance, respiration suspended.

ADDITIONAL: Sandbag over forearm.

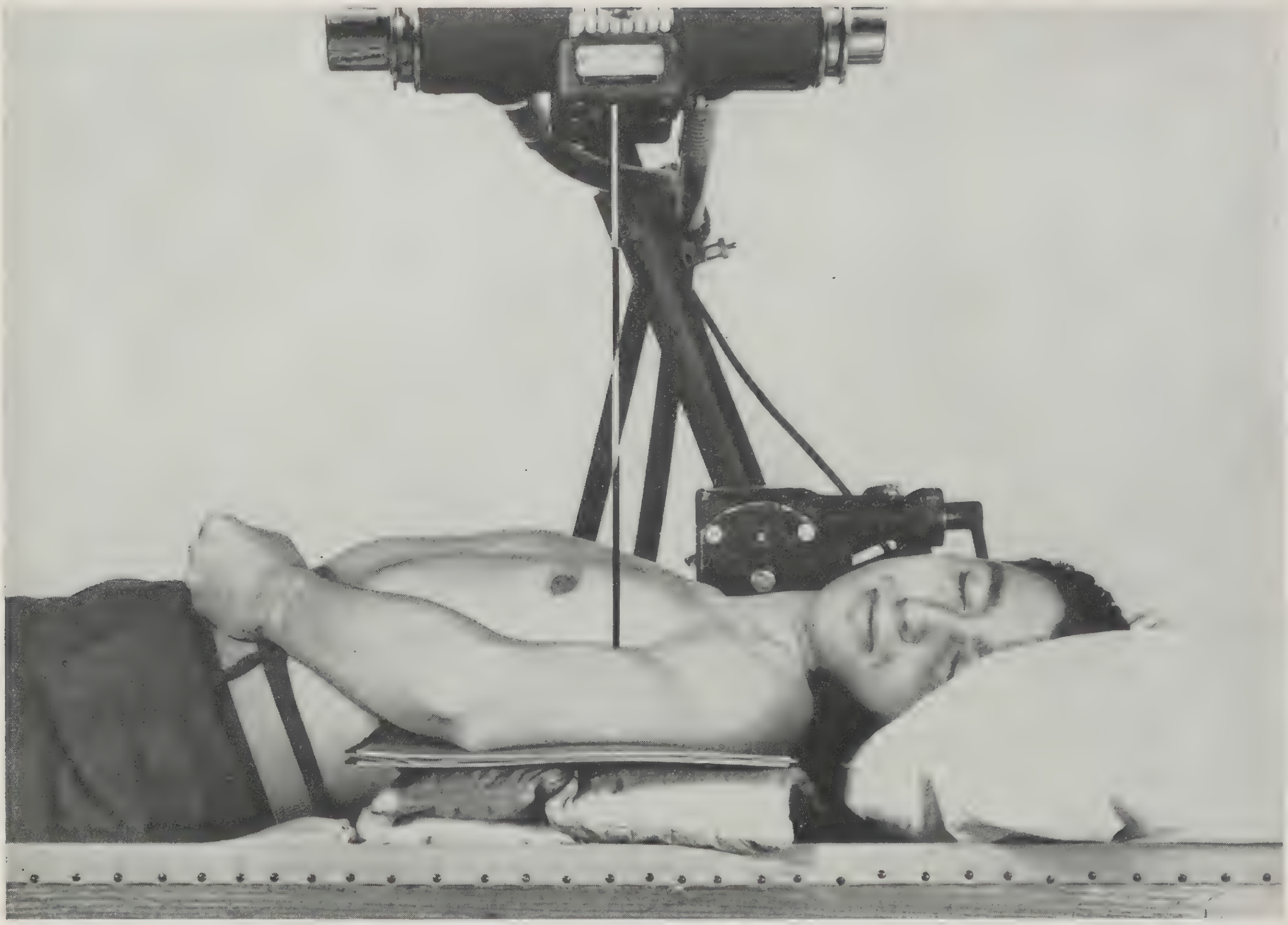
VARIATION: If entire length of bone is desired, use 14 x 17 inch film (½ covered with lead).

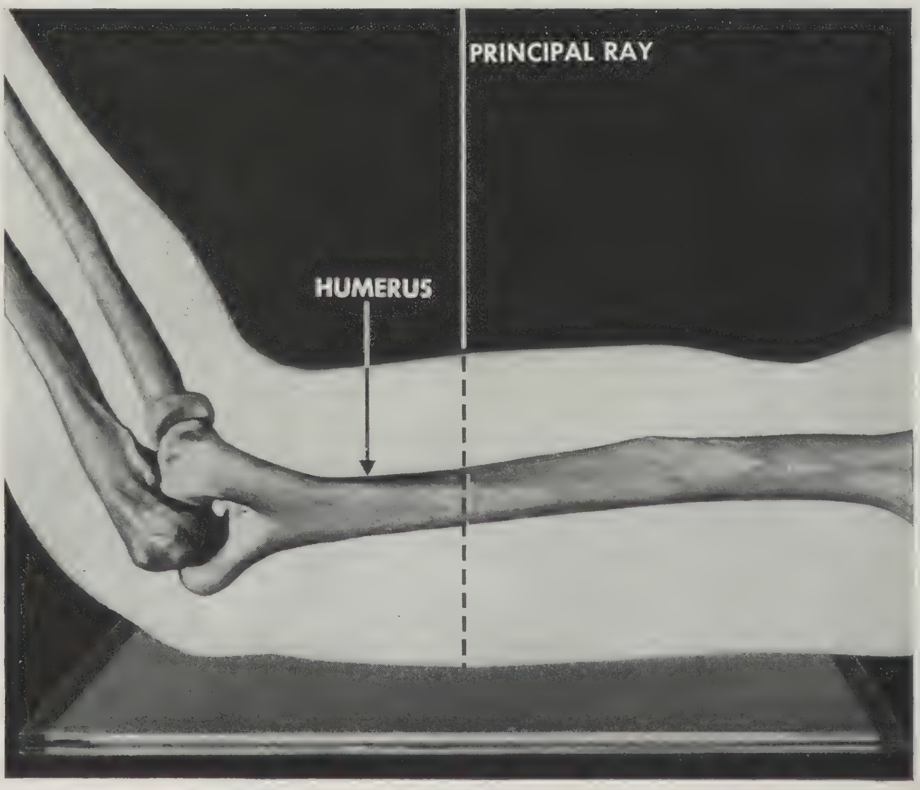
DISTANCE: 30″ Measure through midlength

CMS. THICKNESS		4	5	6	7	8	9	10	11	12	13
VARIABLE KVP	with cardboard holders	68	70	72	74	76	78	80			
	with medium screens	.	.	.	.	.	.	.	72	74	76
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.
MA - SEC		50							4		

AUXILIARIES: CONE, (10 x 12″ with film coverage).

Fig. 132.—ARM (humerus), LATERAL





ANATOMICAL: Humerus and soft tissue.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient supine; arm placed to include joint nearer site of injury—5 cm. from film border.

FOCAL SPOT: Align to center of film.

PRECAUTION: Elbow flexed, forearm resting on abdomen; intercondylar plane perpendicular to film.

ADDITIONAL: Arm raised to shoulder level by using support under film.

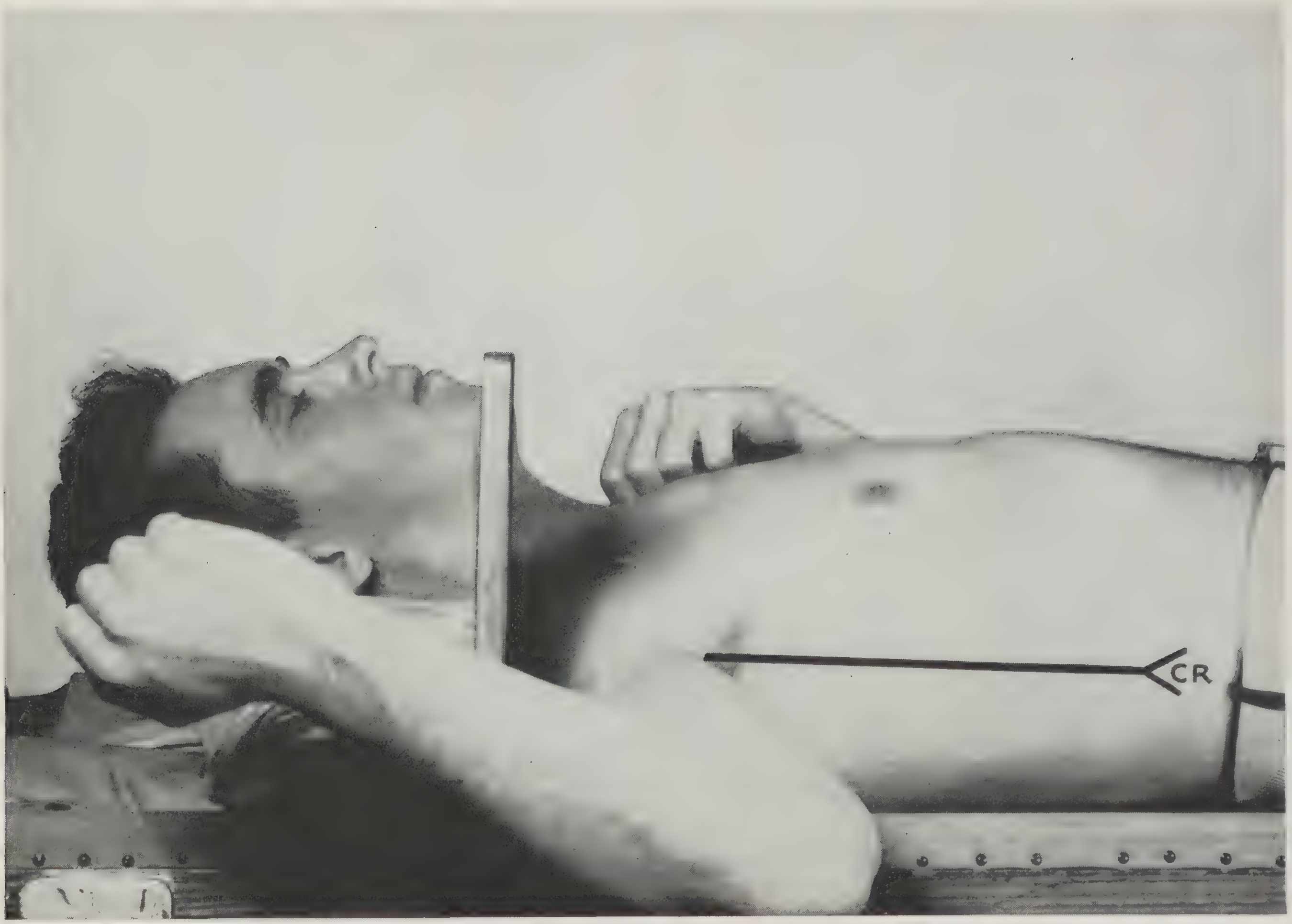
VARIATION: An anteroposterior projection may be made by merely changing the position of the film; placing it behind the arm and angling the principal ray so that it is perpendicular to the film.

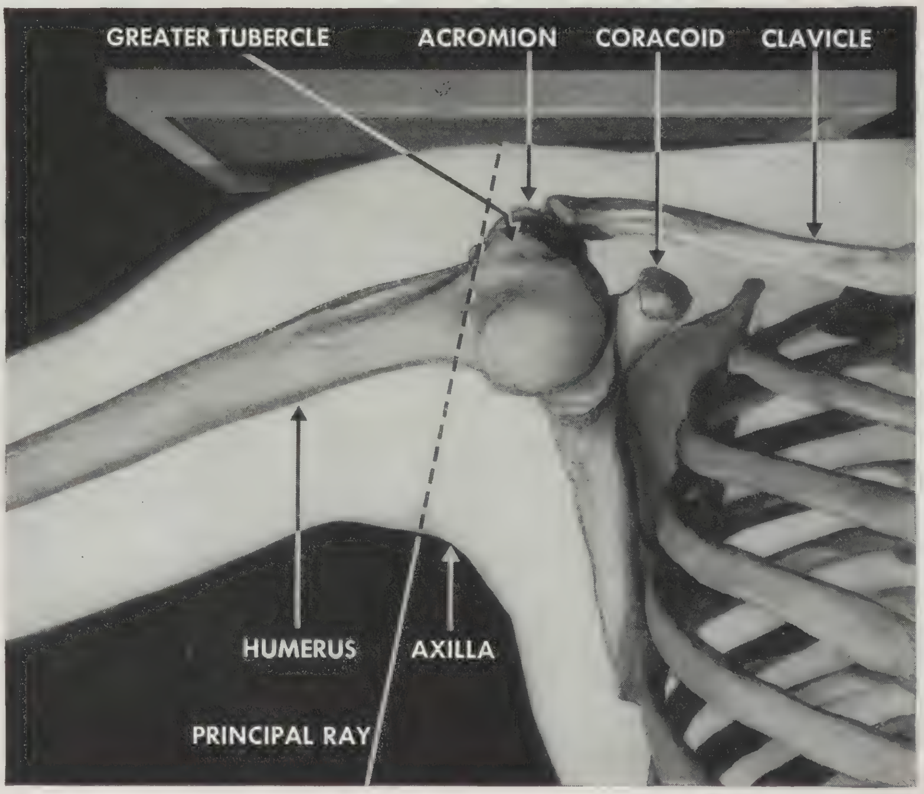
DISTANCE: 30″ Measure through midlength

CMS. THICKNESS		4	5	6	7	8	9	10	11	12	13
VARIABLE KVP	with cardboard holders	68	70	72	74	76	78	80			
	with medium screens	.	.	.	.	.	.	.	72	74	76
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.
MA - SEC.					50					4	

AUXILIARIES: CONE, (10 x 12″ with film coverage).

Fig. 133.—SHOULDER (proximal humerus)





ANATOMICAL: Proximal humerus and soft tissues.

FILM: 10 x 12 inch, vertical.

POSITION: Patient supine, superior surface of shoulder and upper arm in contact with cassette. Tip of acromion to center of film.

FOCAL SPOT: Principal ray directed horizontally to center of axilla.

PRECAUTION: Shoulder elevated as necessary to allow center of image on film. Cassette maintained in position by sandbag.

ADDITIONAL: Sandbag immobilization and support of arm. Grid advisable in heavily muscled individual.

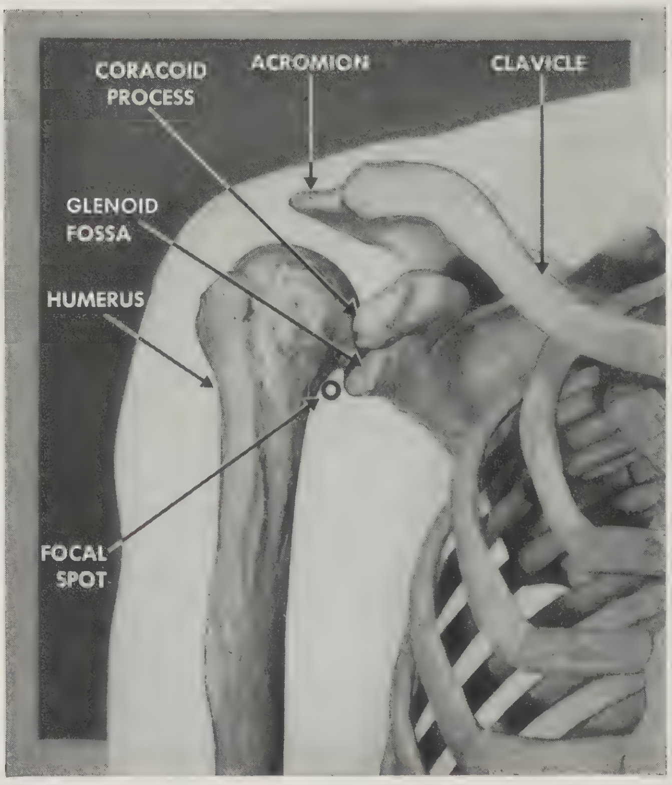
NOTE: Useful in roentgenography after application of airplane splint or abduction cast.

DISTANCE: 30″ Measure through plane from axilla through coracoid process

CMS. THICKNESS		8	9	10	11	12	13	14	15	16	17	18
VARIABLE KVP	with cardboard holders	76	78	80								
	with medium screens				62	64	66					
	with Army wafer grid							68	70	72	74	76
MA - SEC		50			10			20				

AUXILIARIES: CONE.

Fig. 134.—SHOULDER, ANTEROPOSTERIOR



ANATOMICAL: Head of humerus, glenoid fossa, glenohumeral space and soft tissues.

FILM: 10 x 12 inch, widthwise.

POSITION: Patient supine, acromion 5 cm. below midpoint upper border of film. Unaffected side elevated 45°.

FOCAL SPOT: Central ray projected 15° caudally and 10° laterally (toward injured side). Align 2½ cm. laterally and 2½ cm. inferiorly to coracoid process.

PRECAUTIONS: Forearm pronated across abdomen. Humerus aligned with long center axis of film. Respiration suspended.

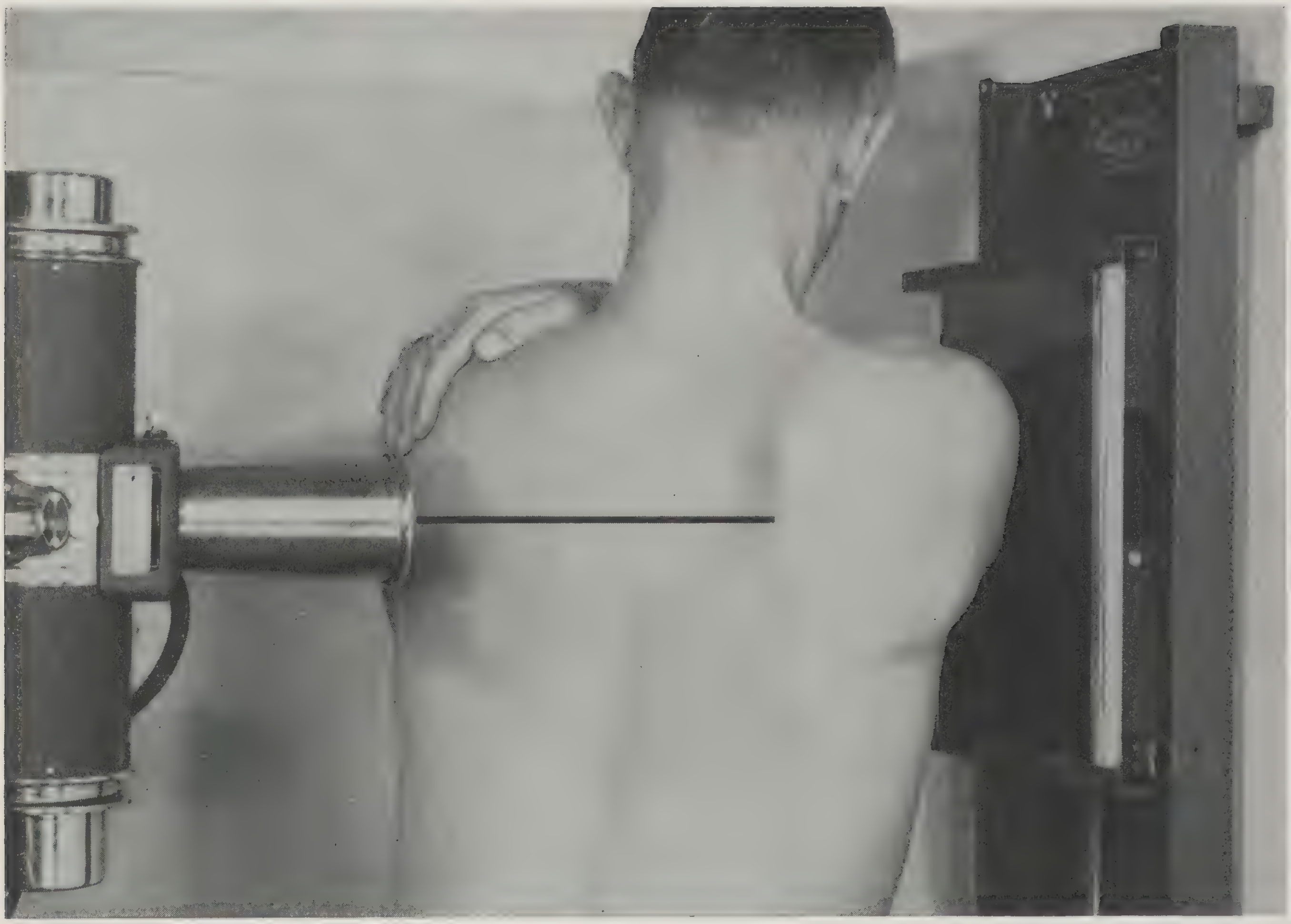
ADDITIONAL: Grid advisable for part measuring 14 cm. or over.

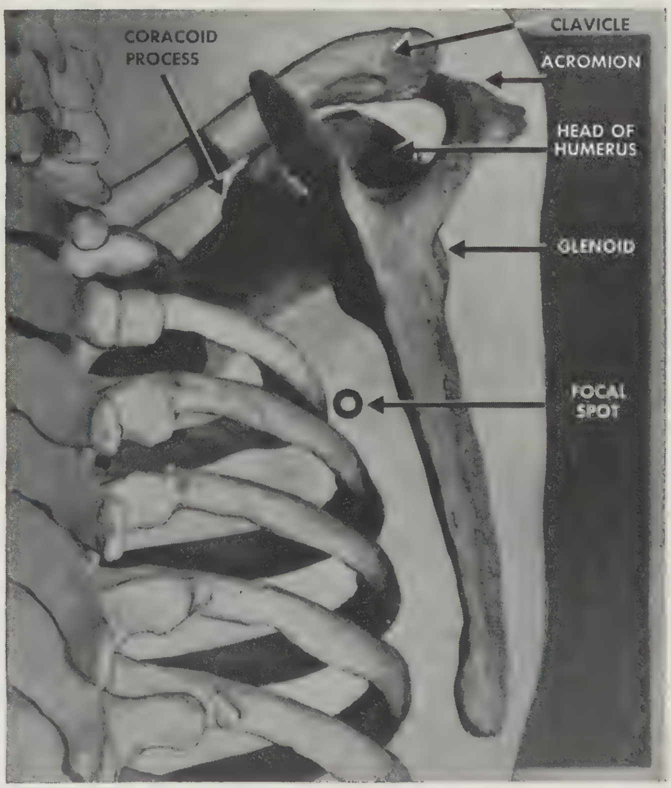
DISTANCE: 30″ Measure through plane across deltoid and coracoid

CMS. THICKNESS		8	9	10	11	12	13	14	15	16	17	18
VARIABLE KVP	with cardboard holders	76	78	80								
	with medium screens				62	64	66					
	with Army wafer grid							68	70	72	74	76
MA - SEC			50			10				20		

AUXILIARIES: CONE, (10 x 12″ with film coverage).

Fig. 135.—SCAPULA, LATERAL





ANATOMICAL: Body of the scapula, acromial process and head of humerus.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient upright, anterior aspect of shoulder against cassette with hand grasping opposite shoulder. Blade of scapula perpendicular to film.

FOCAL SPOT: Align focal spot to point 2 cm. medial to midpart of vertebral border of the scapula —to center of film.

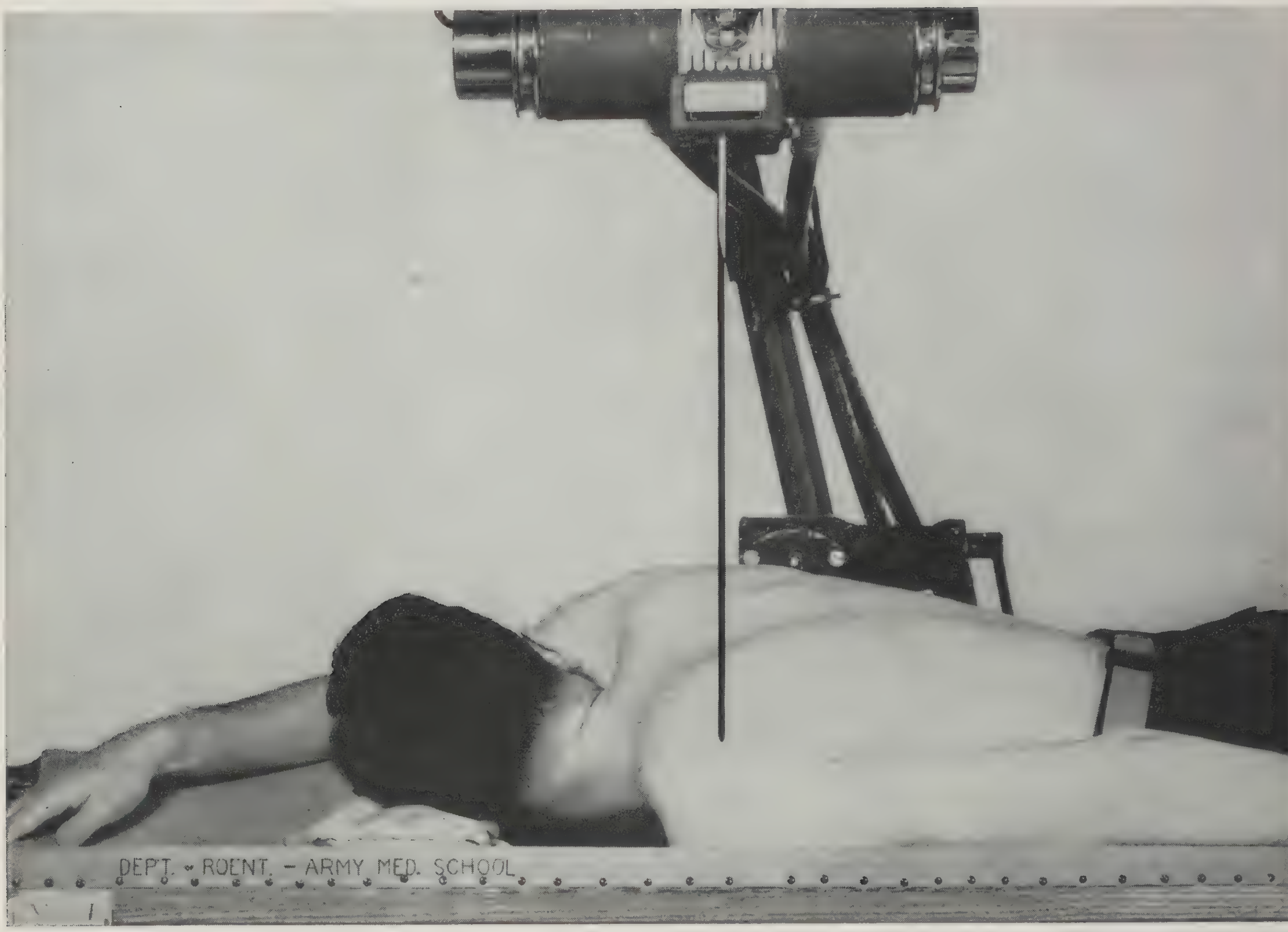
ADDITIONAL: Grid. Respiration suspended.

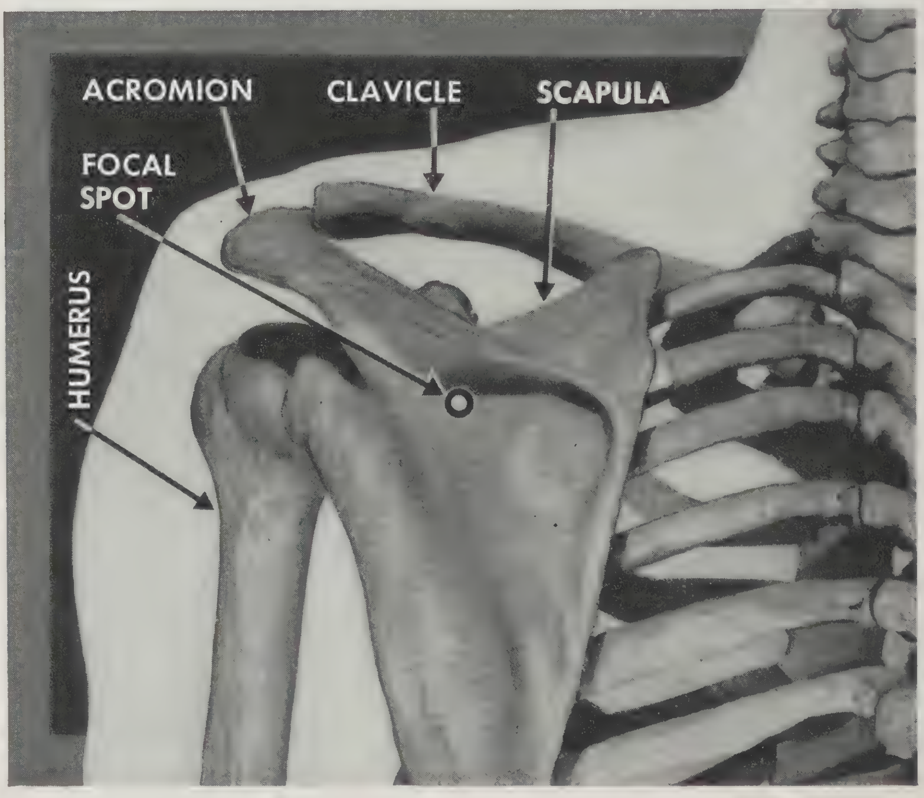
DISTANCE: 30″ — Measure through midplane of vertebral border to the axillary border

CMS. THICKNESS		14	15	16	17	18	19	20	21
VARIABLE KVP	with cardboard holders								
	with medium screens								
	with Army wafer grid	68	70	72	74	76	78	70	72
MA - SEC.		20						40	

AUXILIARIES: CONE.

Fig. 136.—CLAVICLE, POSTERO-ANTERIOR





ANATOMICAL: Clavicle, shoulder joint (or sternoclavicular joint) and soft tissues.

FILM: 10 x 12 inch, widthwise.

POSITION: Patient prone, arm at side and head rotated to opposite side. Tip of acromion 5 cm. below upper border and 5 cm. medial to lateral border of film.

FOCAL SPOT: Align to center of film.

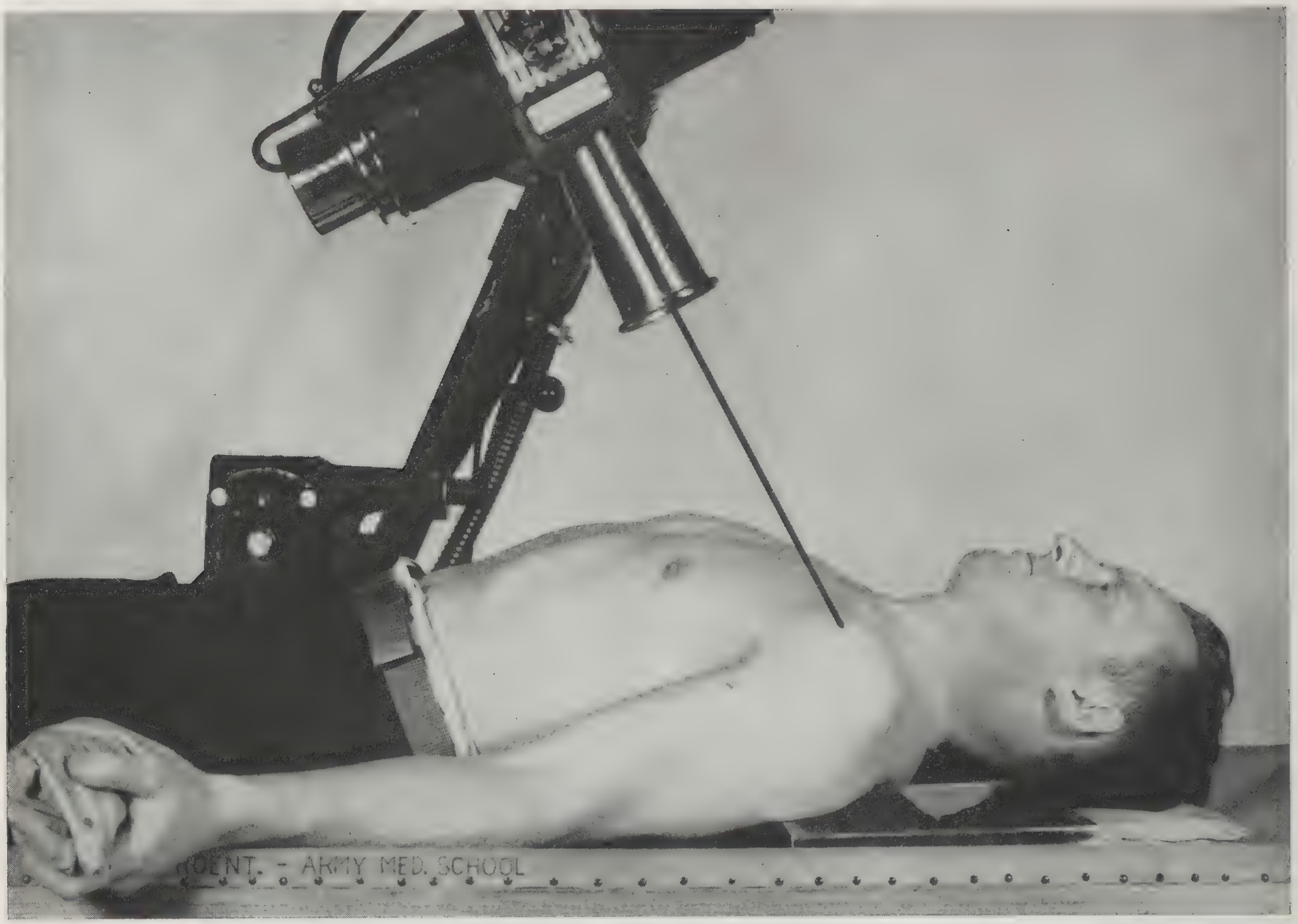
PRECAUTION: Elevate opposite shoulder to secure minimal part-film distance. Suspend respiration.

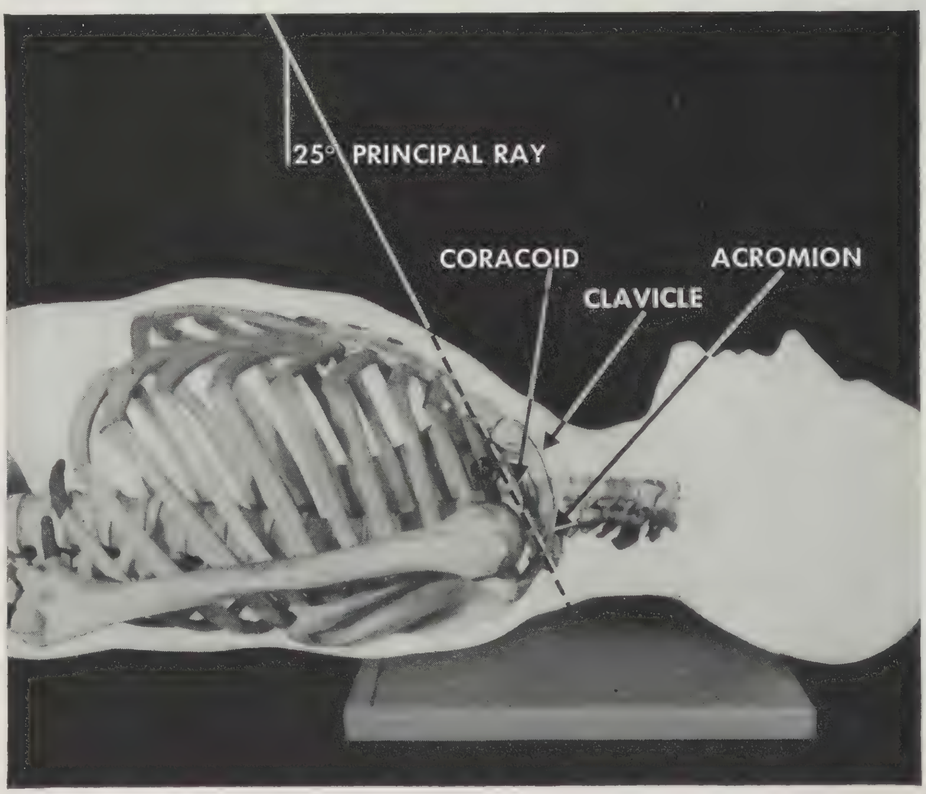
DISTANCE: 30″ Measure through plane across deltoid and coracoid

CMS. THICKNESS		8	9	10	11	12	13	14	15	16	17	18
VARIABLE KVP	with cardboard holders	72	74	76								
	with medium screens				58	60	62					
	with Army wafer grid							64	66	68	70	72
MA - SEC			50			10				20		

AUXILIARIES: CONE, (10 x 12″ with film coverage).

Fig. 137.—SCAPULA, CORACOID PROCESS





ANATOMICAL: Coracoid process.

FILM: 10 x 12 inch, widthwise.

POSITION: Patient supine. Tip of coracoid process over center of film.

FOCAL SPOT: Emergent beam directed 25° cephalad; align principal ray to tip of coracoid.

PRECAUTION: Respiration suspended.

NOTE: Projection of particular value in detection of injuries to coracoid process, acromion and lateral end of clavicle.

DISTANCE: 30″ — Measure through plane across deltoid and coracoid

CMS. THICKNESS		8	9	10	11	12	13	14	15	16	17	18
VARIABLE KVP	with cardboard holders	76	78	80								
	with medium screens				62	64	66					
	with Army wafer grid							68	70	72	74	76
MA - SEC			50			10				20		

AUXILIARIES: CONE (10 x 12″ with film coverage).

Fig. 138.—FOOT, DORSOPLANTAR

ANATOMICAL: Phalanges, metatarsals, tarsals and soft tissues.

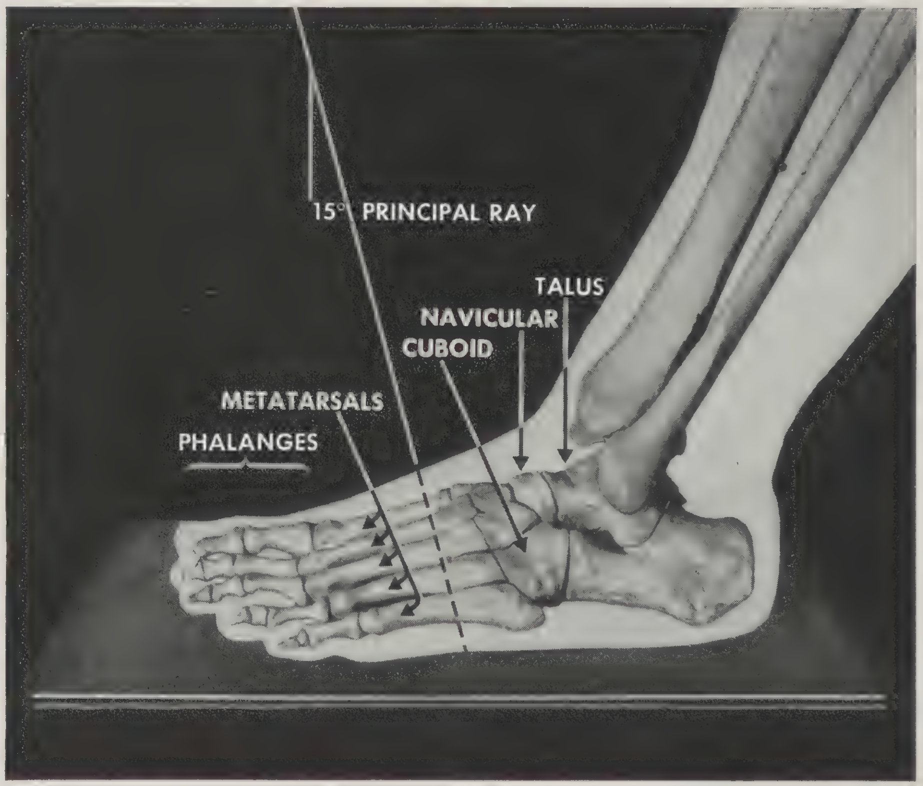
FILM: 10 x 12 inch, lengthwise.

POSITION: Sole of foot firmly in contact with holder, great toe 2 cm. below border of film.

FOCAL SPOT: Align to midpoint of dorsal surface, principal ray directed 15° cephalad to center of film.

PRECAUTION: Toes straight, flat and separated (cotton may be interposed).

VARIATIONS: The above position with angulation of the principal ray medially 15°, gives a more satisfactory view of the articulations between tarsals, and between tarsals and metatarsals.



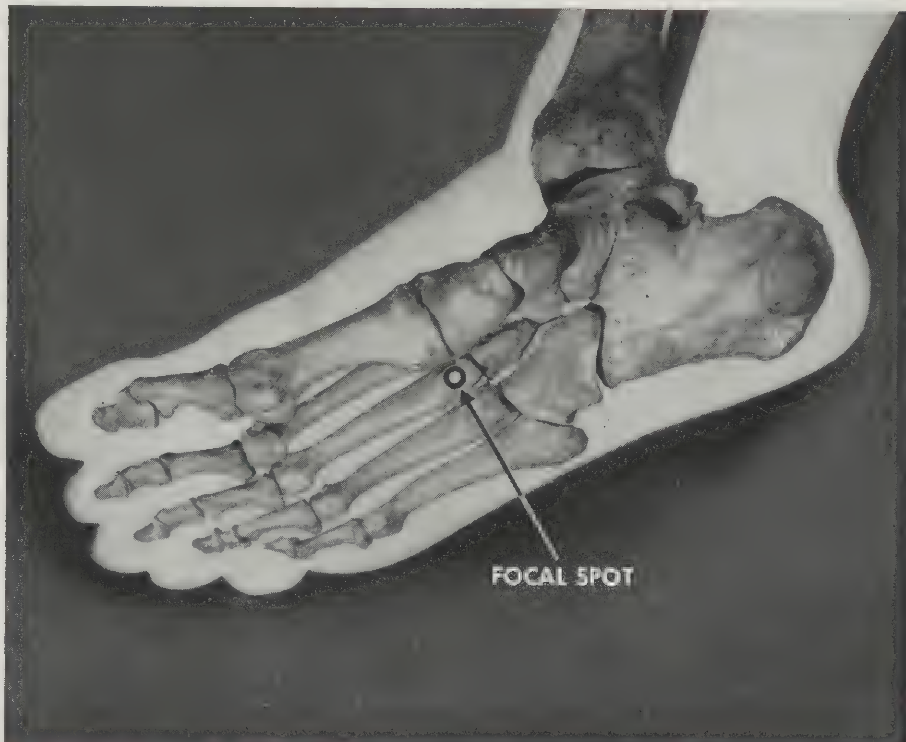
DISTANCE: 30″ Measure through plane of prominence of dorsum

CMS. THICKNESS		4	5	6	7	8	9	10	11	12	13
VARIABLE KVP	with cardboard holders	56	58	60	62	64	66	68			
	with medium screens								70	72	74
	with Army wafer grid										
MA - SEC					50					2	

AUXILIARIES: CONE (10 x 12″ with film coverage).

Fig. 139.—FOOT, PLANTAR-SEMILATERAL

ANATOMICAL: Phalanges, metatarsals, tarsals and soft tissues.
FILM: 10 x 12 inch, obliqued to long axis of foot.
POSITION: Patient prone or semiprone, dorsolateral surface of foot in contact with film, plantar surface forming 45° angle with film.
FOCAL SPOT: Align to center of plantar surface to center of film.
PRECAUTION: Opposite leg drawn up to support and immobilize patient.
ADDITIONAL: Cone may be used, sandbag immobilization if needed.
VARIATIONS: True lateral of foot may be obtained by having patient lie on side with lateral border of foot in contact with film (plantar surface perpendicular to film), principal ray aligned to center of tarsal region.

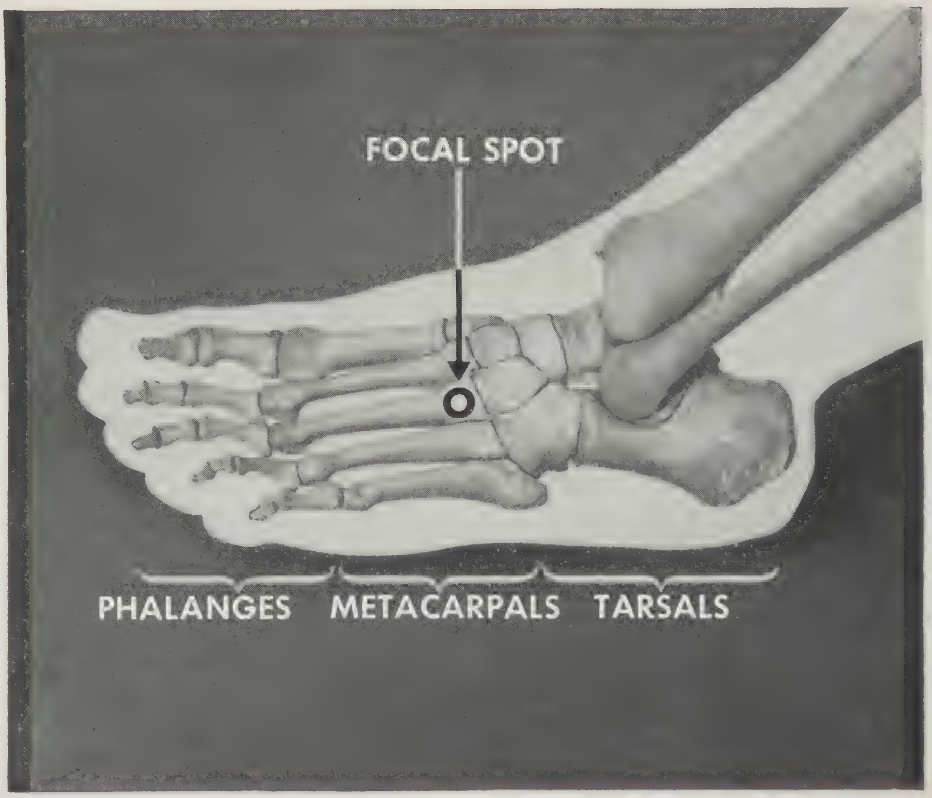


DISTANCE: 30″ — Measure through plane of prominence of dorsum

CMS. THICKNESS		4	5	6	7	8	9	10	11	12	13
VARIABLE KVP	with cardboard holders	58	60	62	64	66	68	70			
	with medium screens	.	.	.	.	.	.	.	72	74	76
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.
MA - SEC					50					2	

AUXILIARIES: CONE (10 x 12″ with film coverage).

Fig. 140.—FOOT, OBLIQUE



ANATOMICAL: Tarsals, metatarsals, phalanges and soft tissues.

FILM: 10 x 12 inch, obliquely positioned.

POSITION: Patient laterally recumbent; foot extended obliquely across film; plane of sole at 45° angle to film surface.

FOCAL SPOT: Align to center of film.

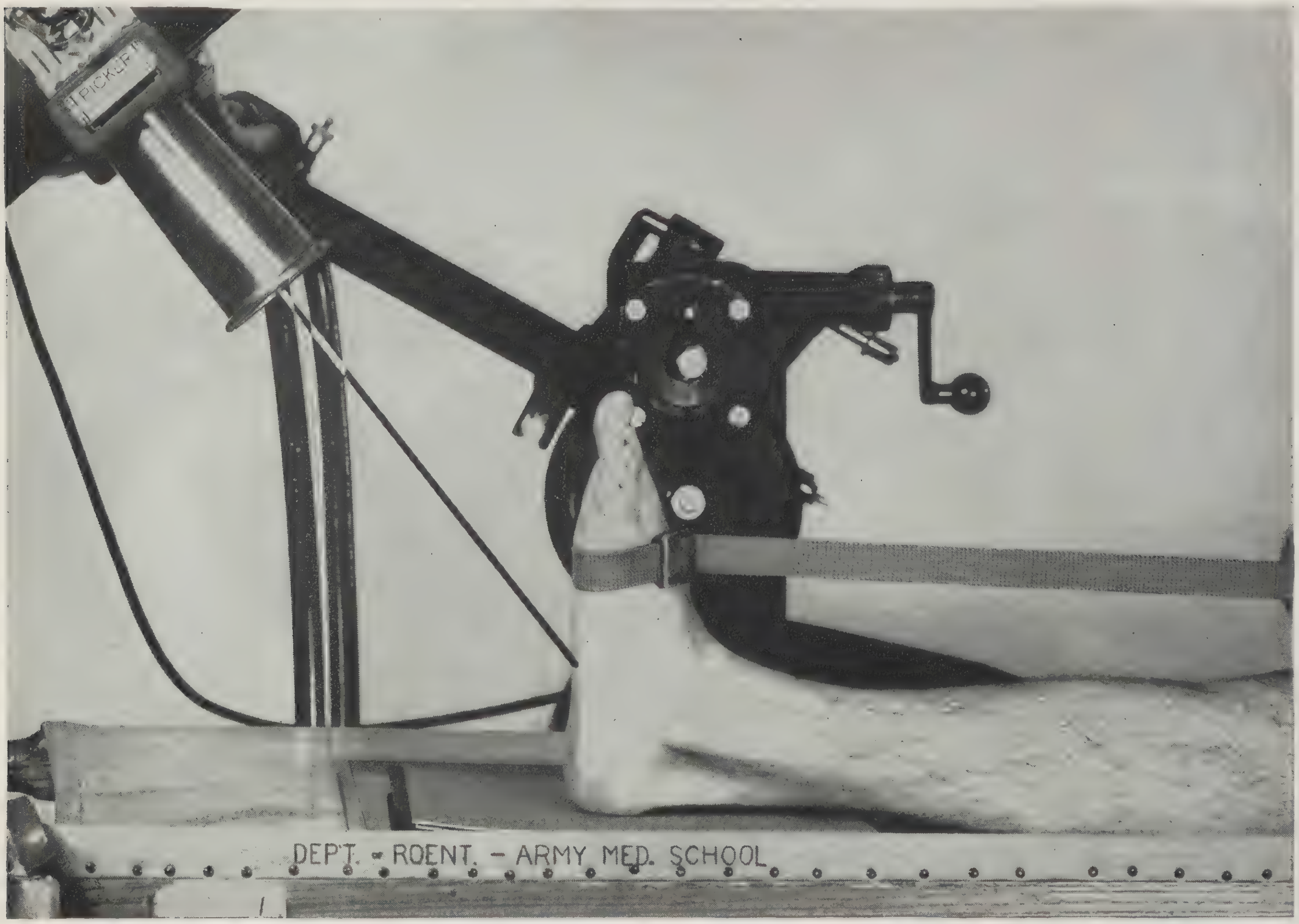
PRECAUTION: Support knee of side under study by opposite knee to prevent motion.

DISTANCE: 30″ Measure through plane of prominence of dorsum

CMS. THICKNESS		4	5	6	7	8	9	10	11	12	13
VARIABLE KVP	with cardboard holders	58	60	62	64	66	68	70			
	with medium screens								72	74	76
	with Army wafer grid										
MA - SEC					50					2	

AUXILIARIES: CONE (10 x 12″ with film coverage).

Fig. 141.—OS CALCIS, INFEROSUPERIOR



ANATOMICAL: Os calcis, malleoli and soft tissues.

FILM: 8 x 10 inch, lengthwise.

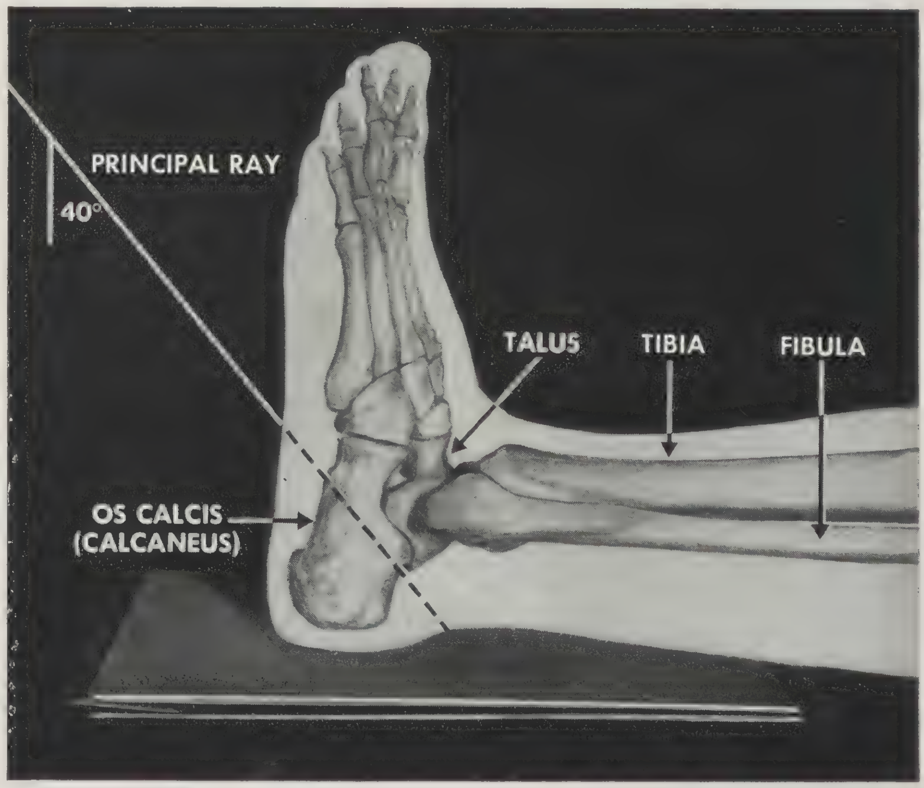
POSITION: Patient sitting or supine, center of heel 5 cm. distal to center of film.

FOCAL SPOT: Tube angled 40°; align to midwidth of foot at junction of middle and posterior thirds of plantar surface (sole of foot).

PRECAUTION: Traction on foot to maintain 90° angle between plantar surface and film.

ADDITIONAL: Immobilization by sandbags to sides of foot.

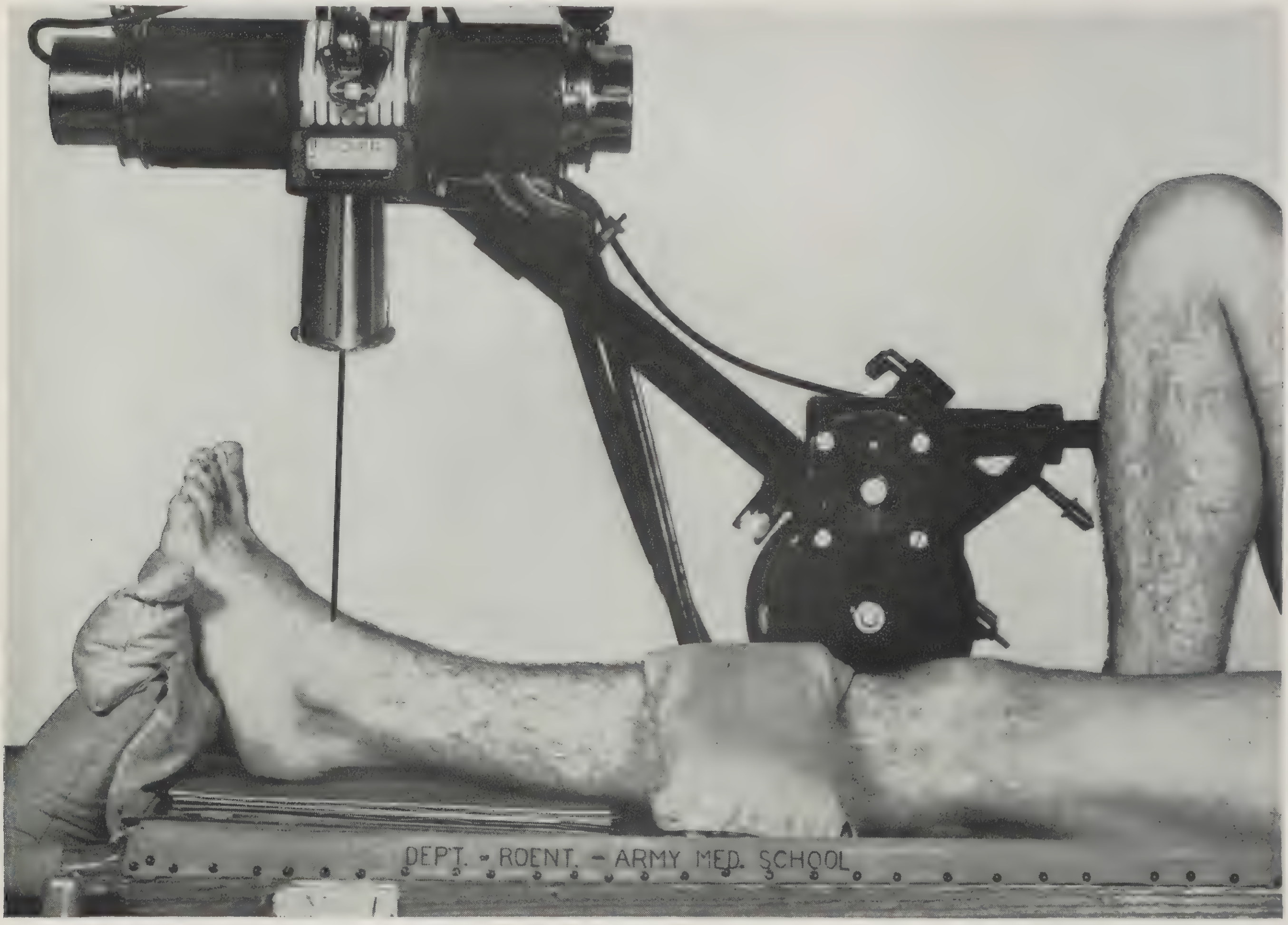
VARIATION: Os calcis may also be demonstrated with patient prone; injured leg supported on sandbags so that foot is vertical, the principal ray directed through posterior surface of heel to strike film placed vertically against the plantar surface.



DISTANCE: 30″ Measure through oblique plane, 8 cms. each way from end of heel

CMS. THICKNESS		6	7	8	9	10	11	12	13	14	15	16
VARIABLE KVP	with cardboard holders	74	76	78	80	82						
	with medium screens	.	.	.	.	.	64	66	68			
	with Army wafer grid	.	.	.	.	.	.	.	.	70	72	74
MA - SEC				50				10			20	

Fig. 142.—ANKLE, ANTEROPOSTERIOR



ANATOMICAL: Talus, distal tibia and fibula, ankle joint and soft tissues.

FILM: 8 x 10 inch, lengthwise.

POSITION: Patient supine, internal malleolus at midlength of film.

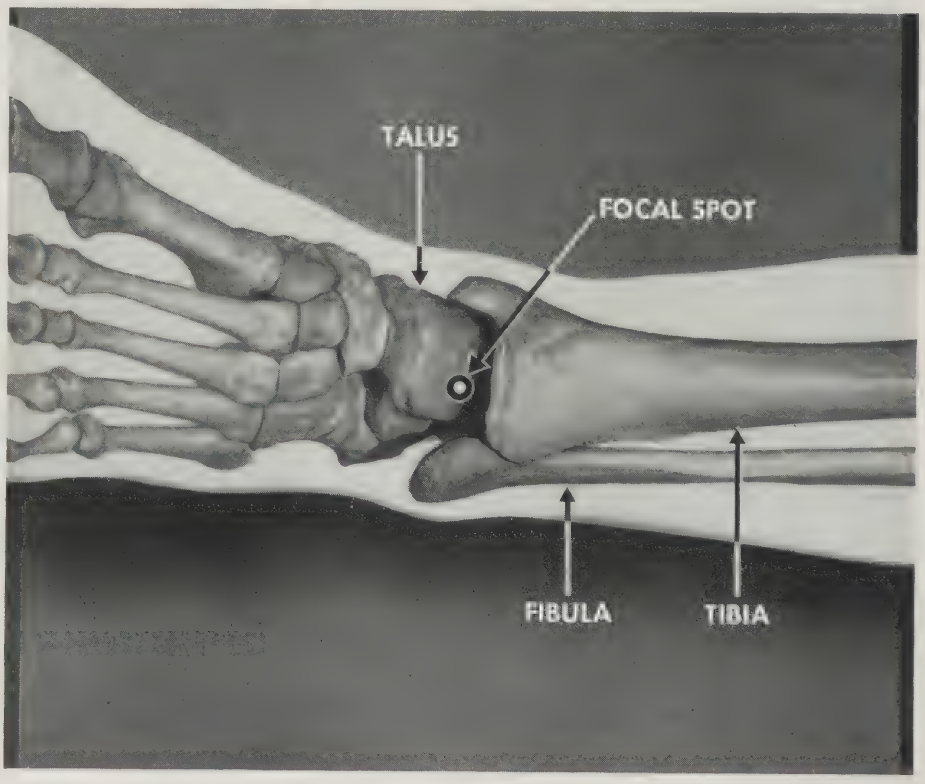
FOCAL SPOT: Align to midwidth of ankle, at level of prominence of internal malleolus.

PRECAUTION: Slight internal rotation (until plane of condyle is parallel to film).

ADDITIONAL: Immobilization with sandbags—leg and foot.

VARIATION: An unobstructed view of the lower end of the fibulá may be obtained by internally rotating the foot 10°–15°, principal ray remaining vertical.

NOTE: Fracture of lower end of tibia demands examination of entire length of fibula.

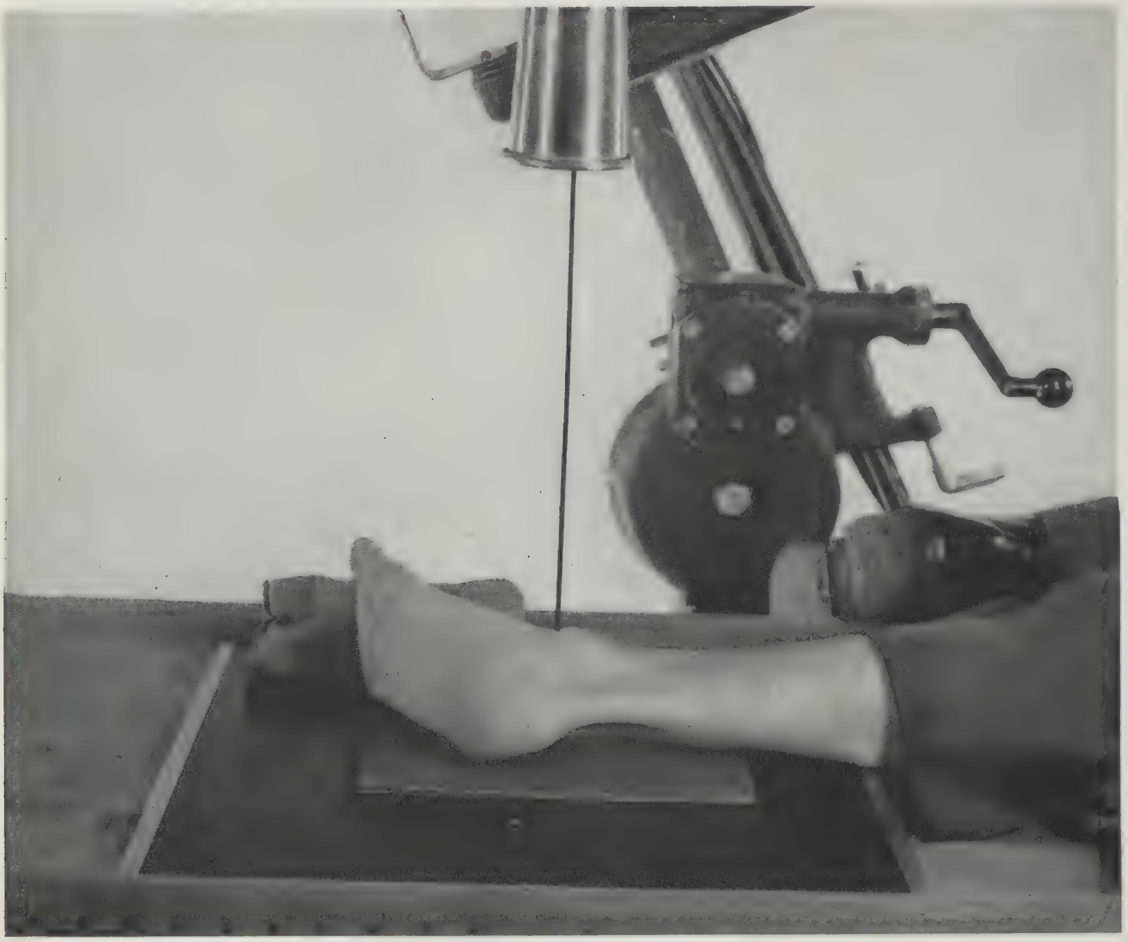


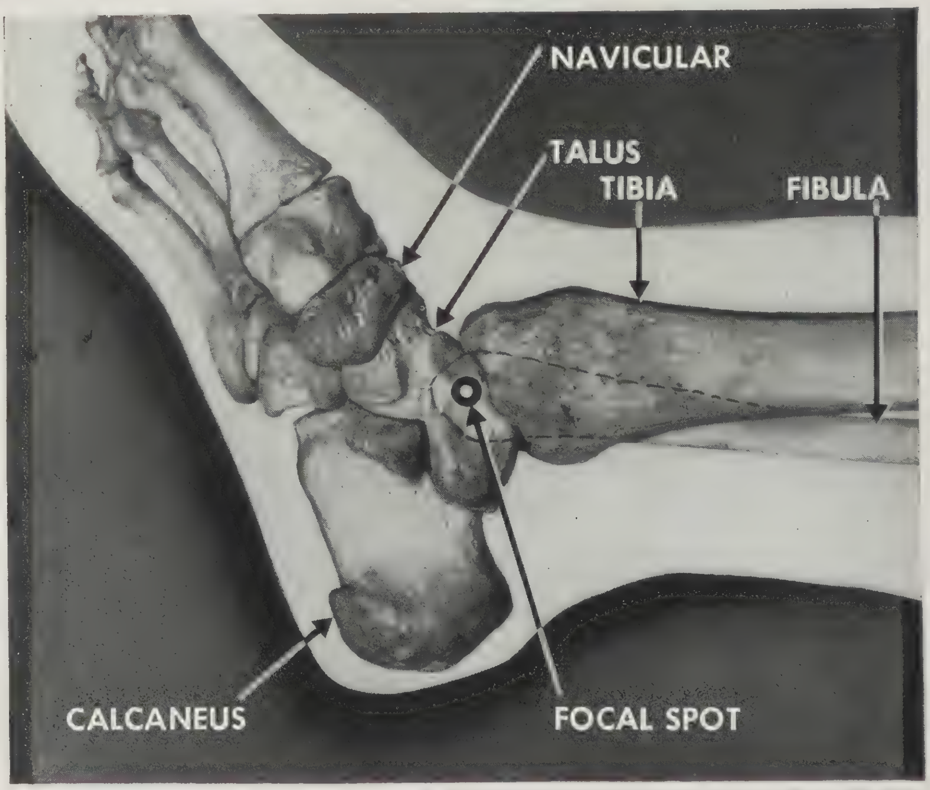
DISTANCE: 30″ | Measure through plane of malleoli

CMS. THICKNESS		4	5	6	7	8	9	10	11	12	13
VARIABLE KVP	with cardboard holders	60	62	64	66	68	70	72			
	with medium screens	.	.	.	.	.	.	.	74	76	78
	with Army wafer grid .	.	.	.	.	.	.	.	.	.	.
MA - SEC					50					2	

AUXILIARIES: CONE.

Fig. 143.—ANKLE, LATERAL





ANATOMICAL: Talotibial articulation, calcaneus, tarsal bones, distal tibia and fibula and soft tissues.

FILM: 8 x 10 inch, lengthwise.

POSITION: Patient laterally recumbent, external malleolus to center of film.

FOCAL SPOT: Align to point 1 cm. distal to tip of internal malleolus and direct principal ray to center of film.

PRECAUTIONS: Intermalleolar plane perpendicular to film. Sandbag elevation of knee and of toes.

ADDITIONAL: Immobilization of leg if needed. Cone may be used.

DISTANCE: 30″		Measure through plane of malleoli, laterally									
CMS. THICKNESS		4	5	6	7	8	9	10	11	12	13
VARIABLE KVP	with cardboard holders	62	64	66	68	70	72	74			
	with medium screens	.	.	.	.	.	.	.	76	78	80
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.
MA - SEC		50							1.5		

AUXILIARIES: CONE.

Fig. 144.—ANKLE, LATERAL (stretcher patient)

ANATOMICAL: As for preceding position.

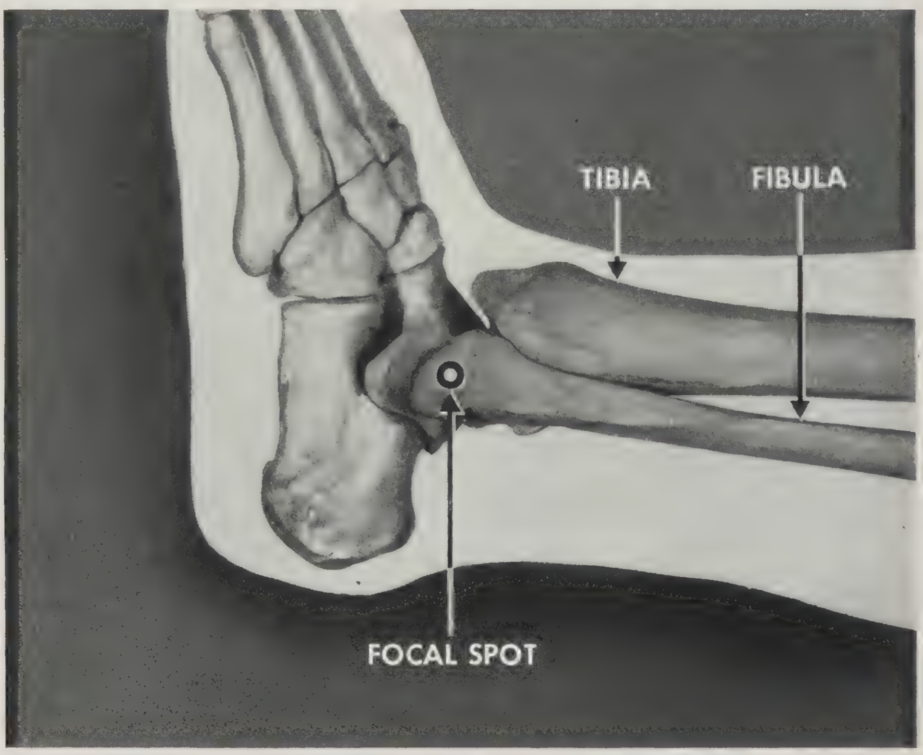
FILM: 8 x 10 inch, vertical, lengthwise.

POSITION: Patient supine, foot upright, intermalleolar plane as nearly horizontal as possible, lateral malleolus at center of film.

FOCAL SPOT: Align to 1 cm. distal to medial malleolus.

PRECAUTION: Elevation and immobilization of ankle with nonopaque support.

ADDITIONAL: Immobilization with sandbags—upper third of leg, if needed.



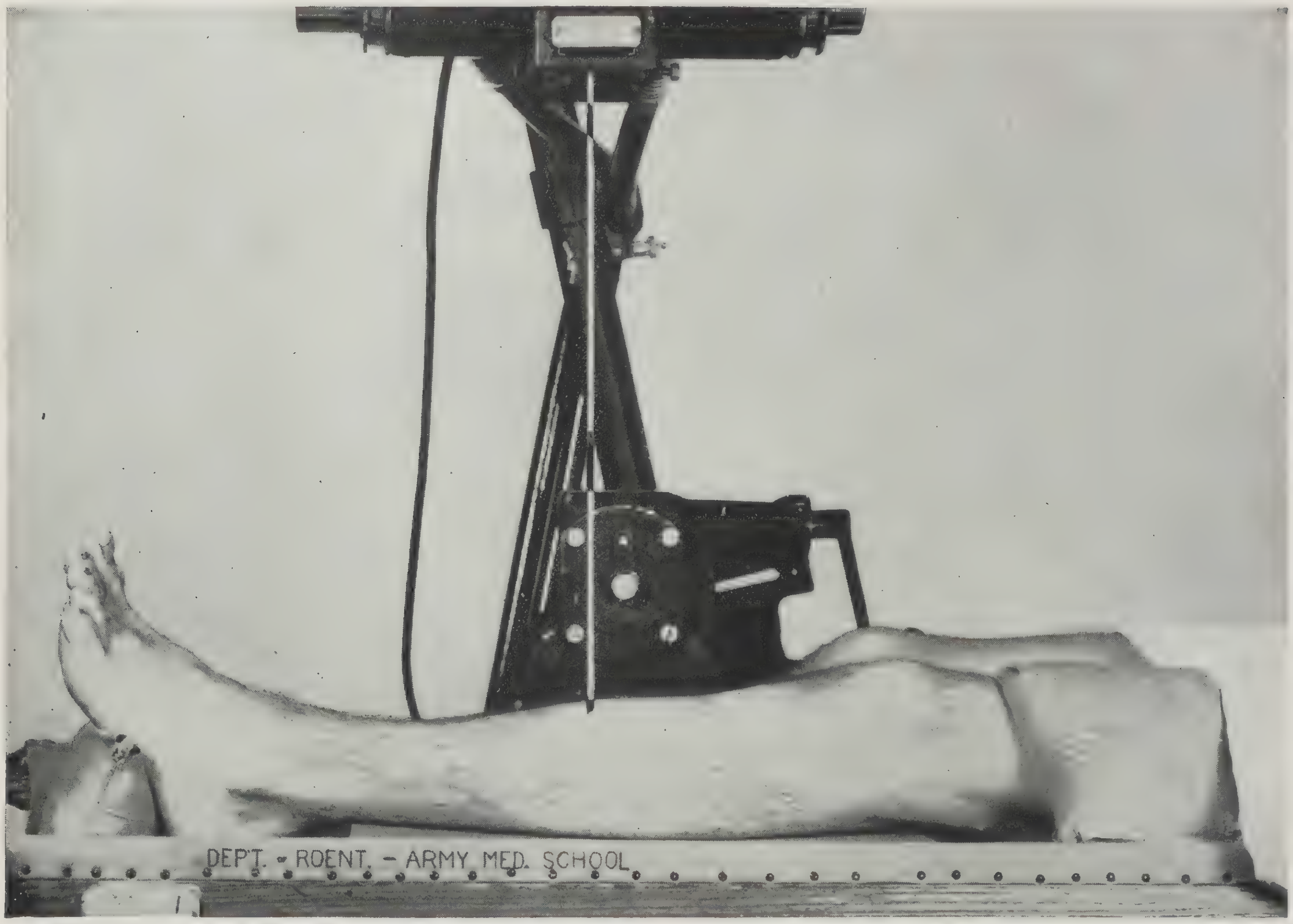
DISTANCE: 30″ Measure through plane of malleoli, laterally

CMS. THICKNESS		4	5	6	7	8	9	10	11	12	13
VARIABLE KVP	with cardboard holders	62	64	66	68	70	72	74			
	with medium screens								76	78	80
	with Army wafer grid										
MA - SEC					50					1.5	

AUXILIARIES: CONE.

See lateral ankle.

Fig. 145.—LEG (tibia and fibula), ANTEROPOSTERIOR



ANATOMICAL: Tibia and fibula, soft tissues.

FILM: 14 x 17 inch, lengthwise, one-half masked.

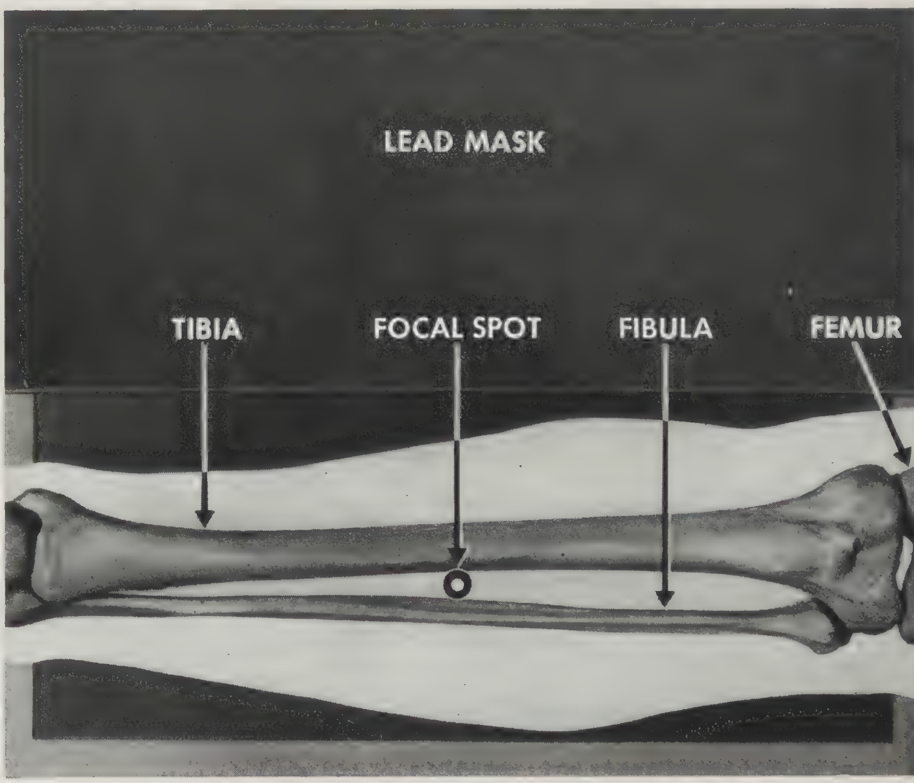
POSITION: Patient supine; joint nearer site of injury 5 cm. from end of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Intermalleolar plane parallel to film. (Slight internal rotation.)

ADDITIONAL: Immobilization by sandbags—sides of foot and across thigh.

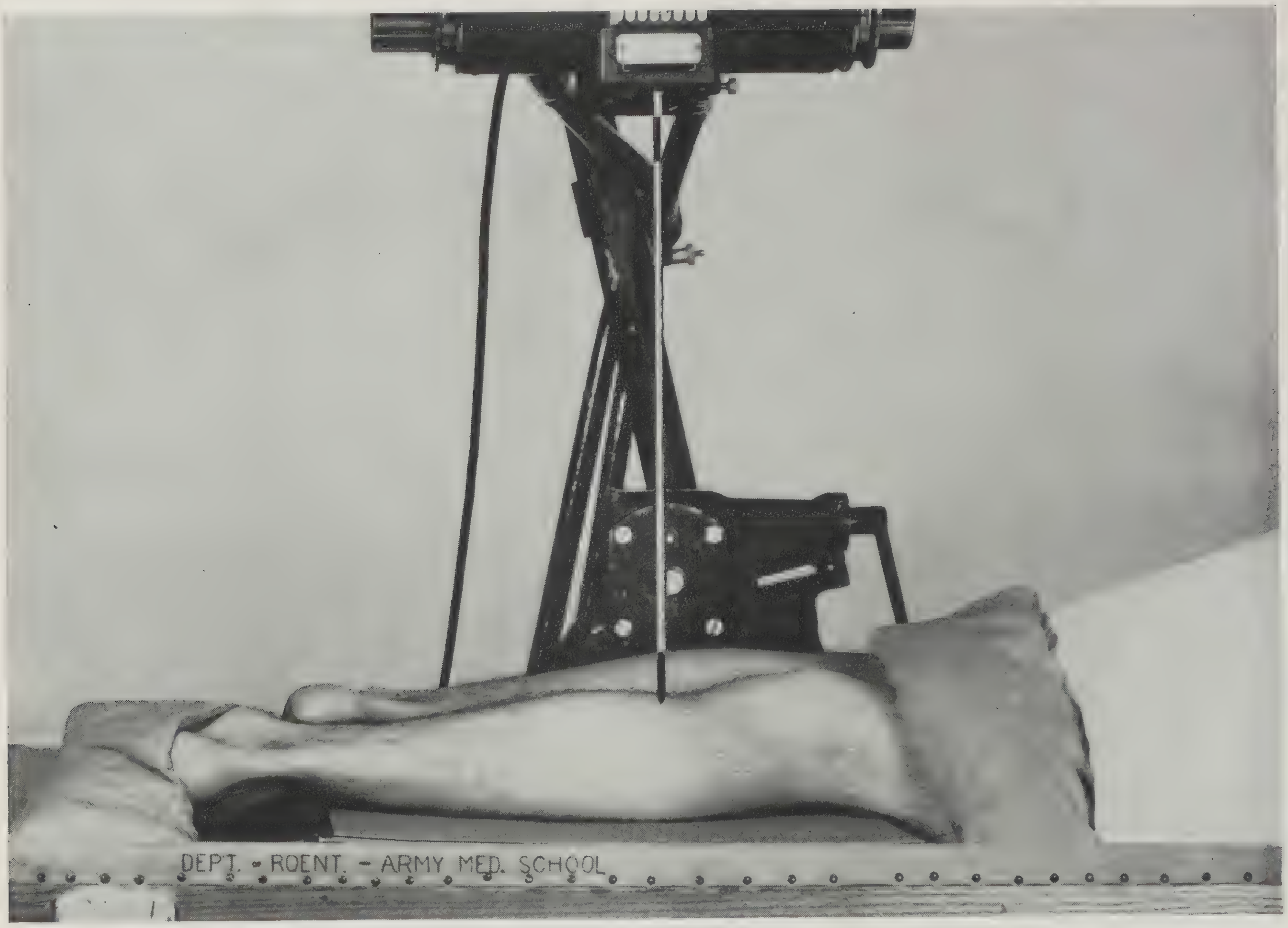
VARIATIONS: Severe injury requires sufficient projections to include both bones throughout their entire length.



DISTANCE: 30″ — Measure through midlength

CMS. THICKNESS		6	7	8	9	10	11	12	13	14	15	16
VARIABLE KVP	with cardboard holders	62	64	66	68	70						
	with medium screens	.	.	.	.	.	62	64	66			
	with Army wafer grid	.	.	.	.	.	.	.	.	68	70	72
MA-SEC				50				4			8	

Fig. 146.—LEG (tibia and fibula) LATERAL



ANATOMICAL: As for preceding position.

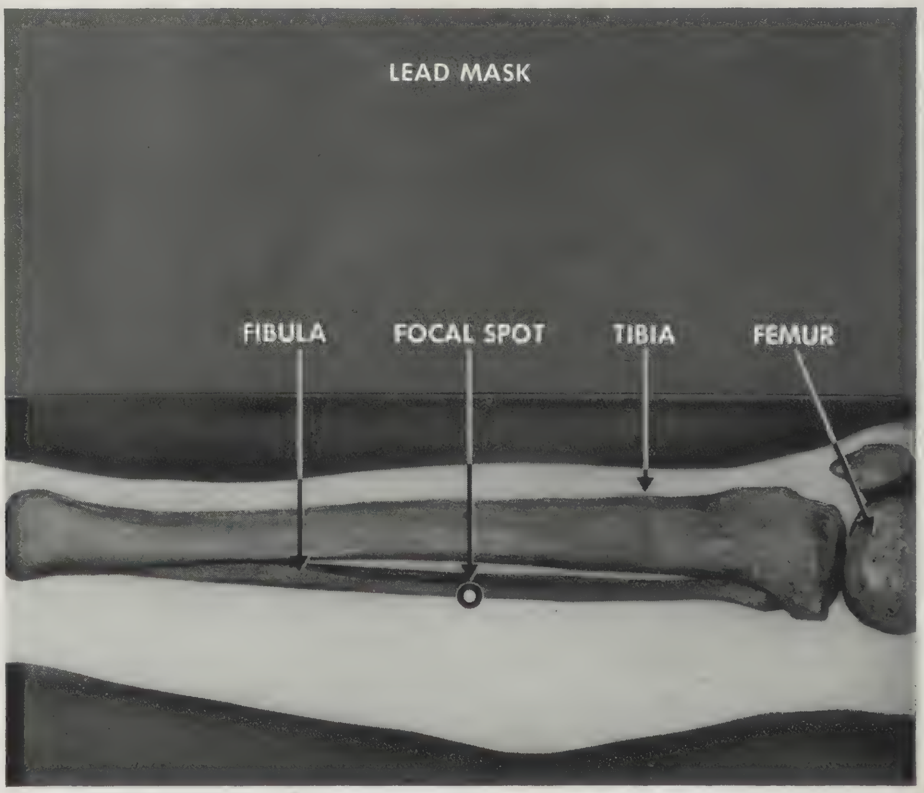
FILM: 14 x 17 inch, lengthwise, one-half masked.

POSITION: Patient laterally recumbent, lateral surface against film; joint nearer site of injury 5 cm. from end of film.

FOCAL SPOT: Align to center of film.

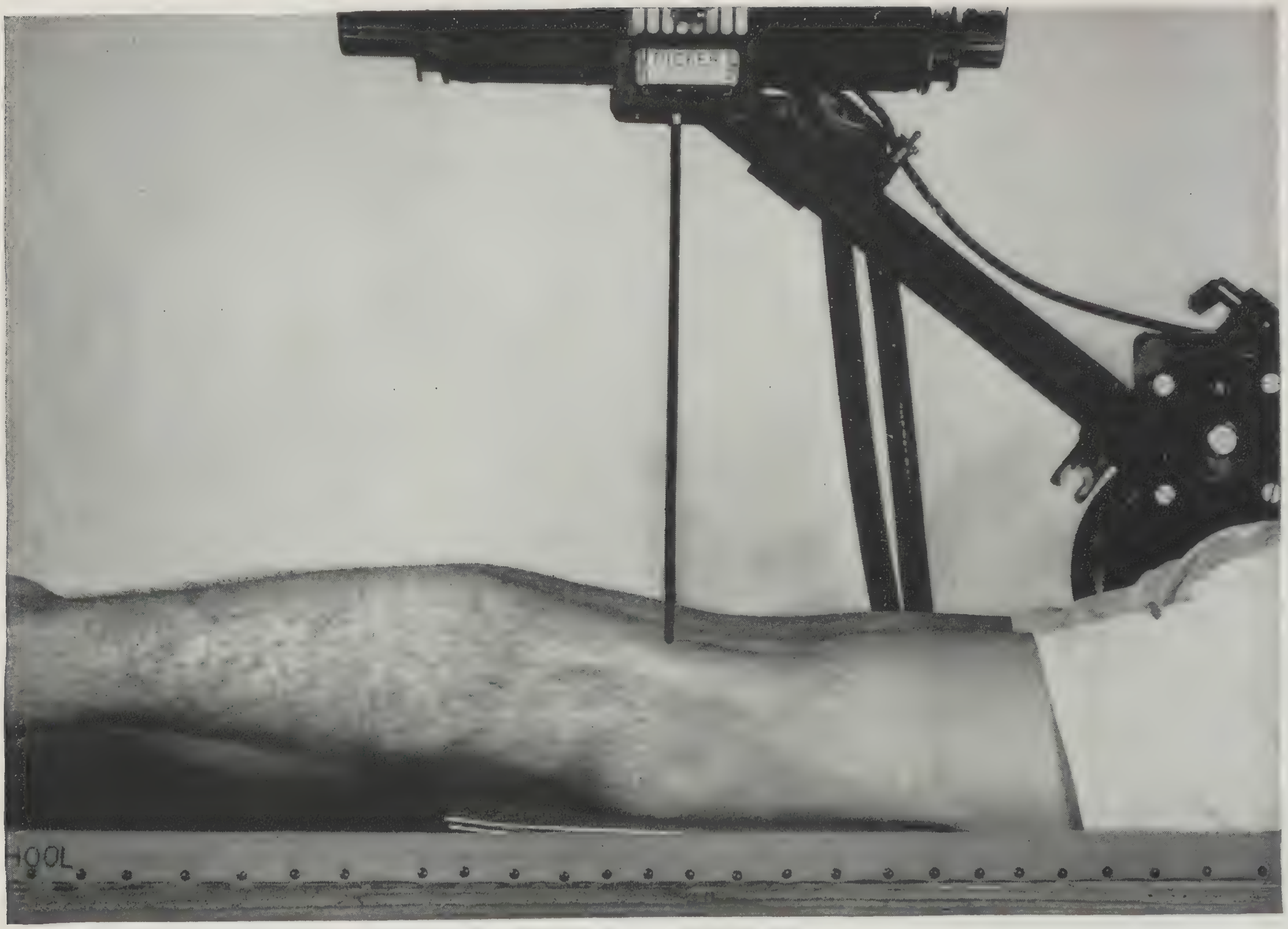
PRECAUTION: Plane through tibial condyles perpendicular to film. Opposite leg flexed and thrown forward; toes raised by sandbag.

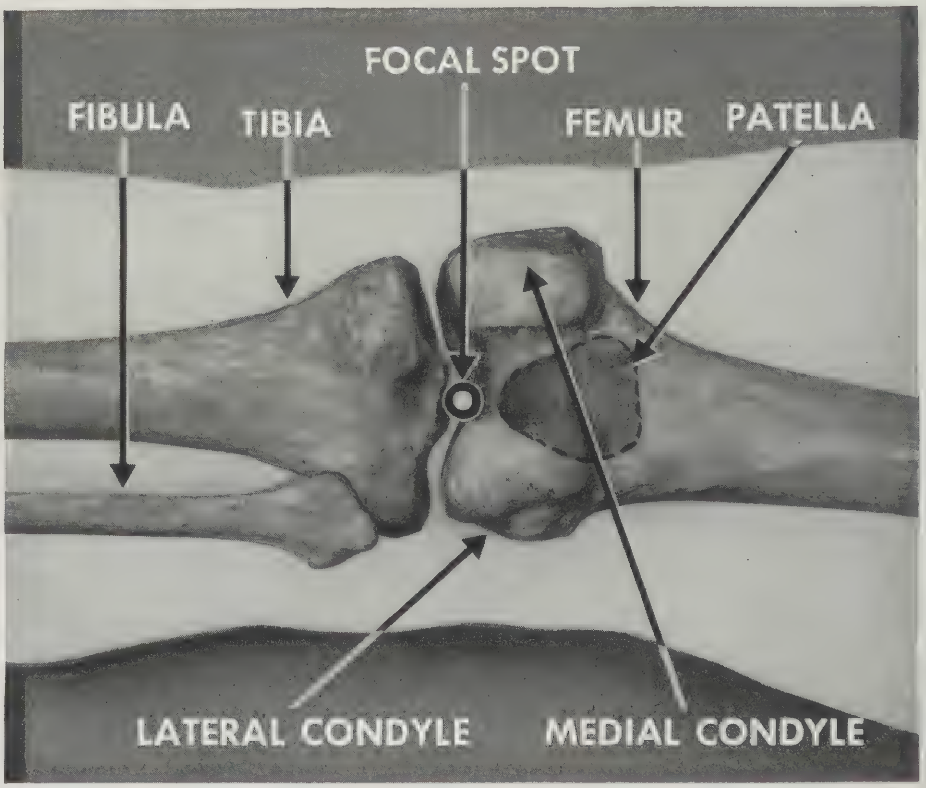
ADDITIONAL: Immobilization by sandbags—over foot and across thigh.



DISTANCE: 30″												Measure through midlength
CMS. THICKNESS		6	7	8	9	10	11	12	13	14	15	16
VARIABLE KVP	with cardboard holders	62	64	66	68	70						
	with medium screens						62	64	66			
	with Army wafer grid									68	70	72
MA - SEC				50				4			8	

Fig. 147.—KNEE, POSTERO-ANTERIOR





ANATOMICAL: Tibiofemoral articulation, proximal tibia and fibula, patella and soft tissues.

FILM: 8 x 10 inch, lengthwise.

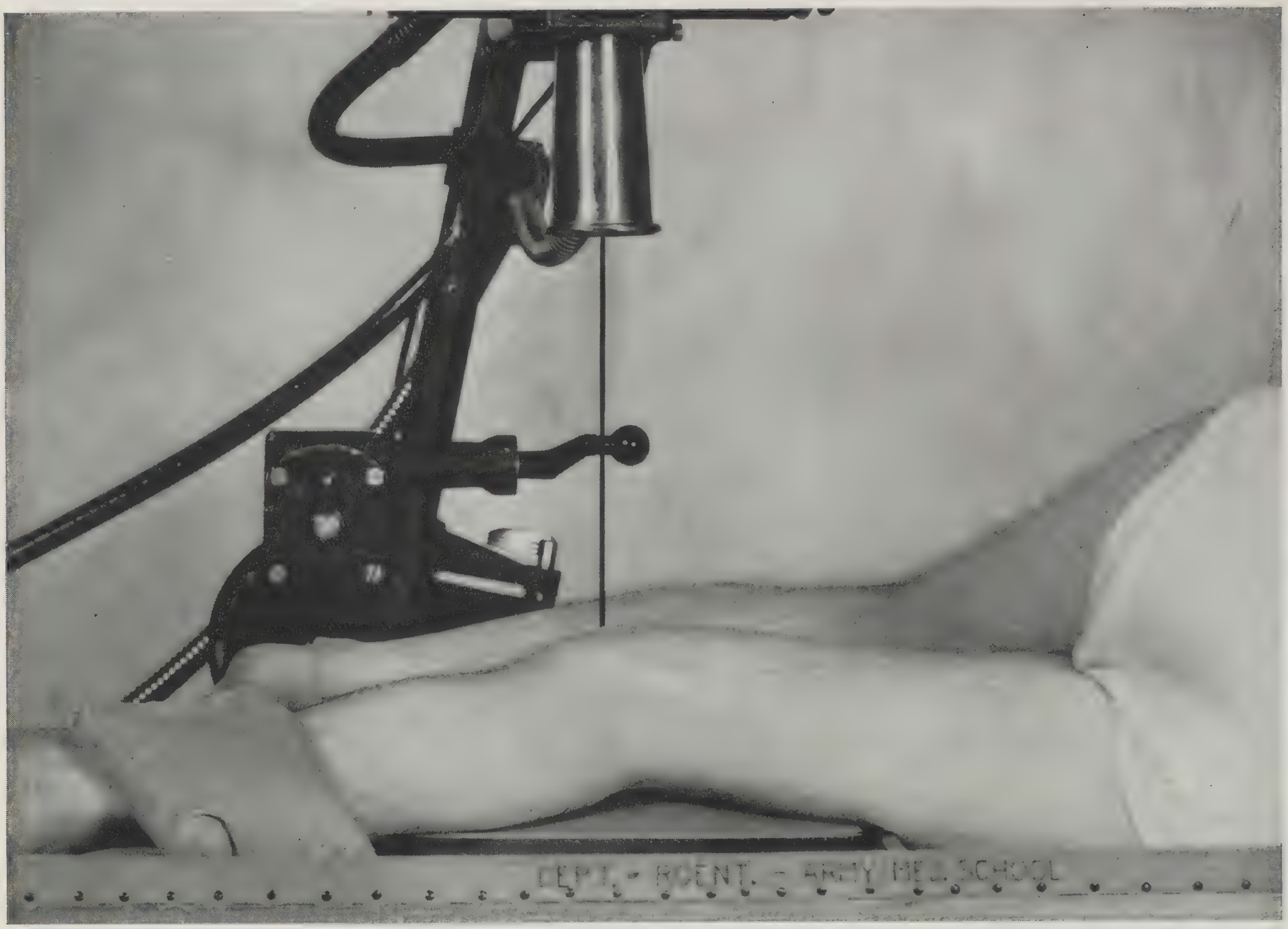
POSITION: Patient prone, lower border of patella to center of film. (Supports above and below knee, in case of injury.)

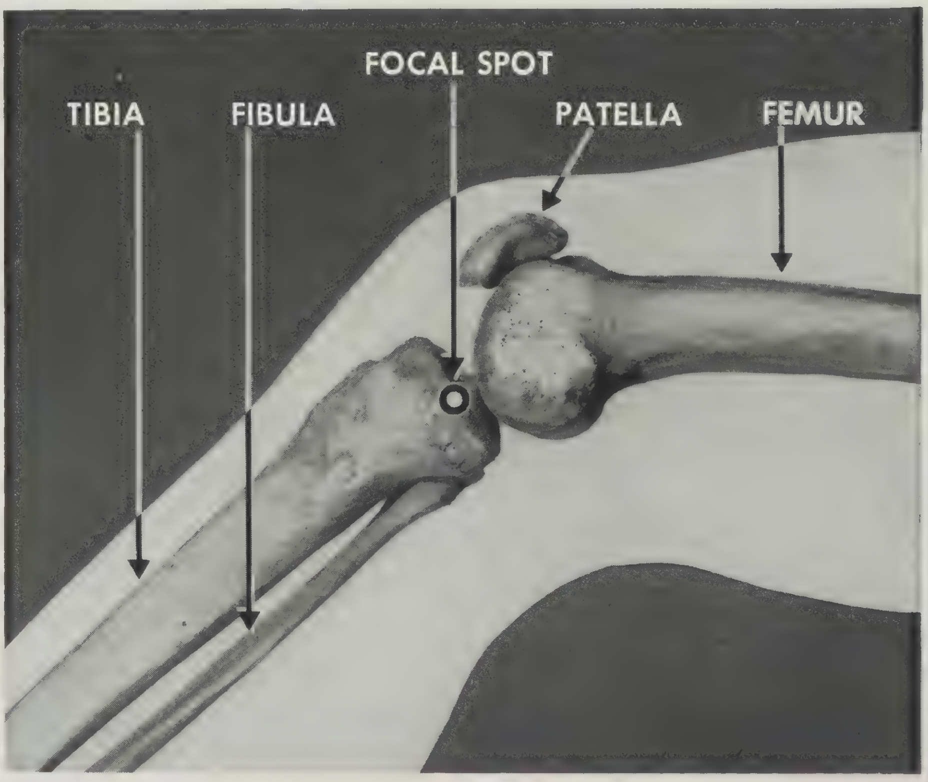
FOCAL SPOT: Center of popliteal fossa (3 cm. proximal to level of head of fibula).

VARIATIONS: Satisfactory roentgenograms can be secured in the A.P. position by directing the principal ray 5° cephalad, aligning to point 1 cm. distal to lower border of the patella.

DISTANCE: 30″		Measure through plane of lower border of patella										
CMS. THICKNESS		6	7	8	9	10	11	12	13	14	15	16
VARIABLE KVP	with cardboard holders	66	68	70	72	74						
	with medium screens						66	68	70			
	with Army wafer grid									72	74	76
MA-SEC				50				3			6	

Fig. 148.—KNEE, LATERAL





ANATOMICAL: See preceding position.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient laterally recumbent, head of fibula 3 cm. below the center of the film; knee in 45° flexion.

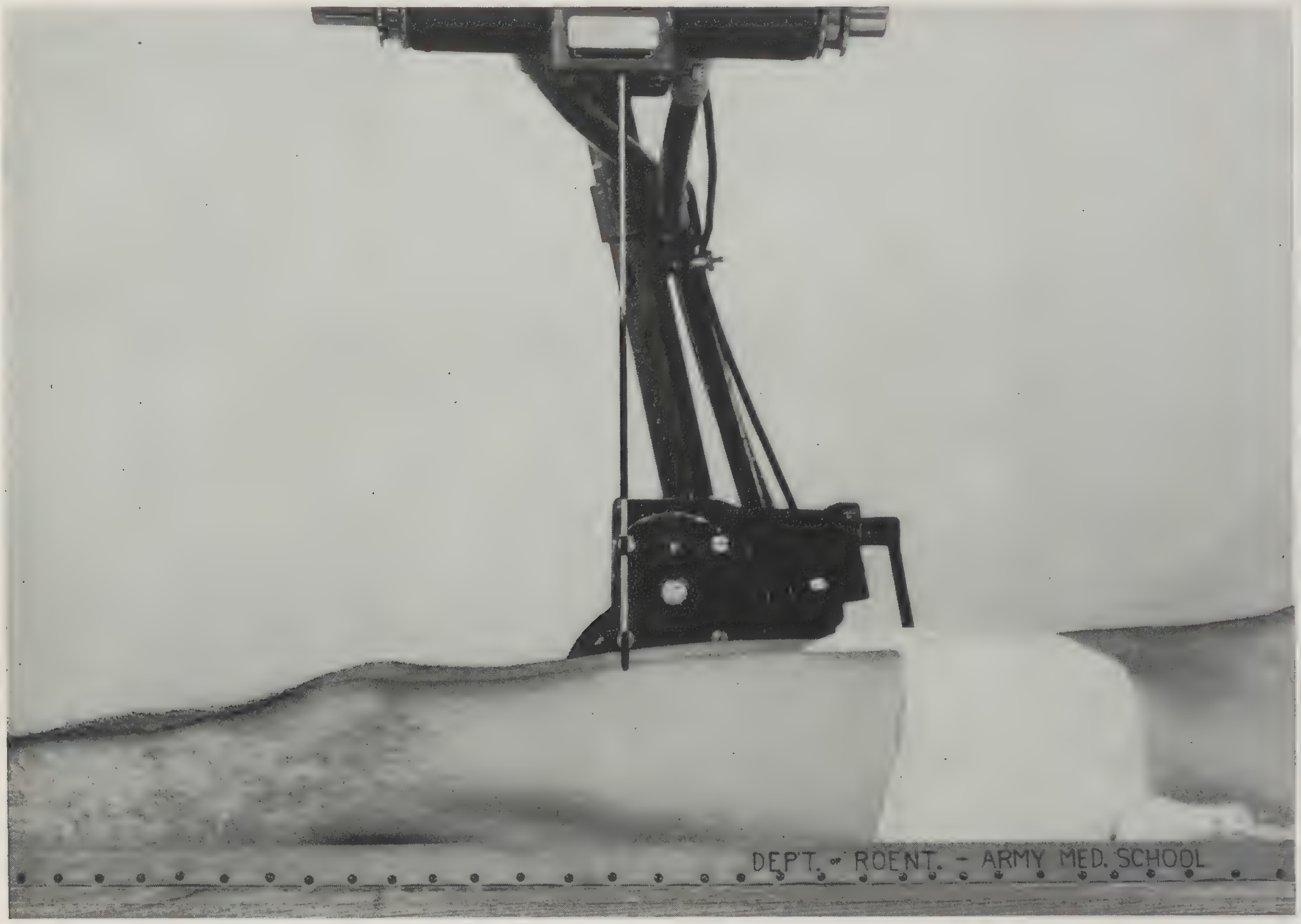
FOCAL SPOT: Align to mid-width upper border of internal *tibial* condyle.

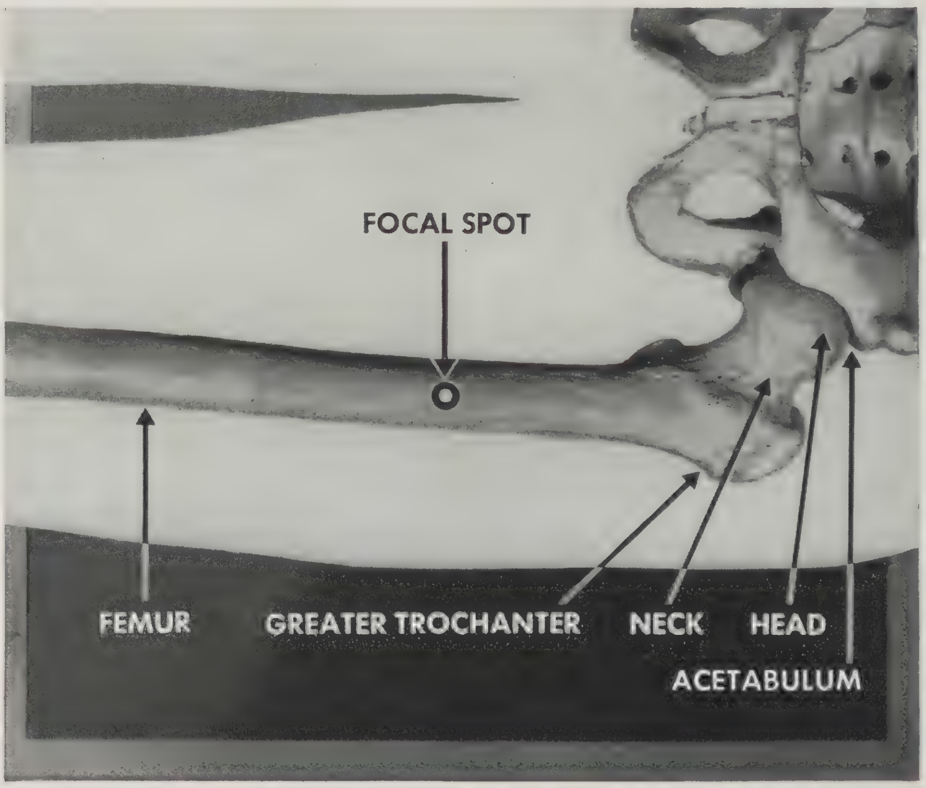
PRECAUTIONS: Plane of condyles perpendicular to the film (sandbag under heel). Opposite leg thrown forward.

DISTANCE: 30″ — Measure through plane of lower border of patella

CMS. THICKNESS		6	7	8	9	10	11	12	13	14	15	16
VARIABLE KVP	with cardboard holders	66	68	70	72	74						
	with medium screens						66	68	70			
	with Army wafer grid									72	74	76
MA - SEC				50				3			6	

Fig. 149.—THIGH (femur) ANTEROPOSTERIOR





ANATOMICAL: Femur and soft tissues.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient supine, joint nearer site of injury 7 cm. from end of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Slight internal rotation of foot (to bring condylar plane and neck of femur parallel to film).

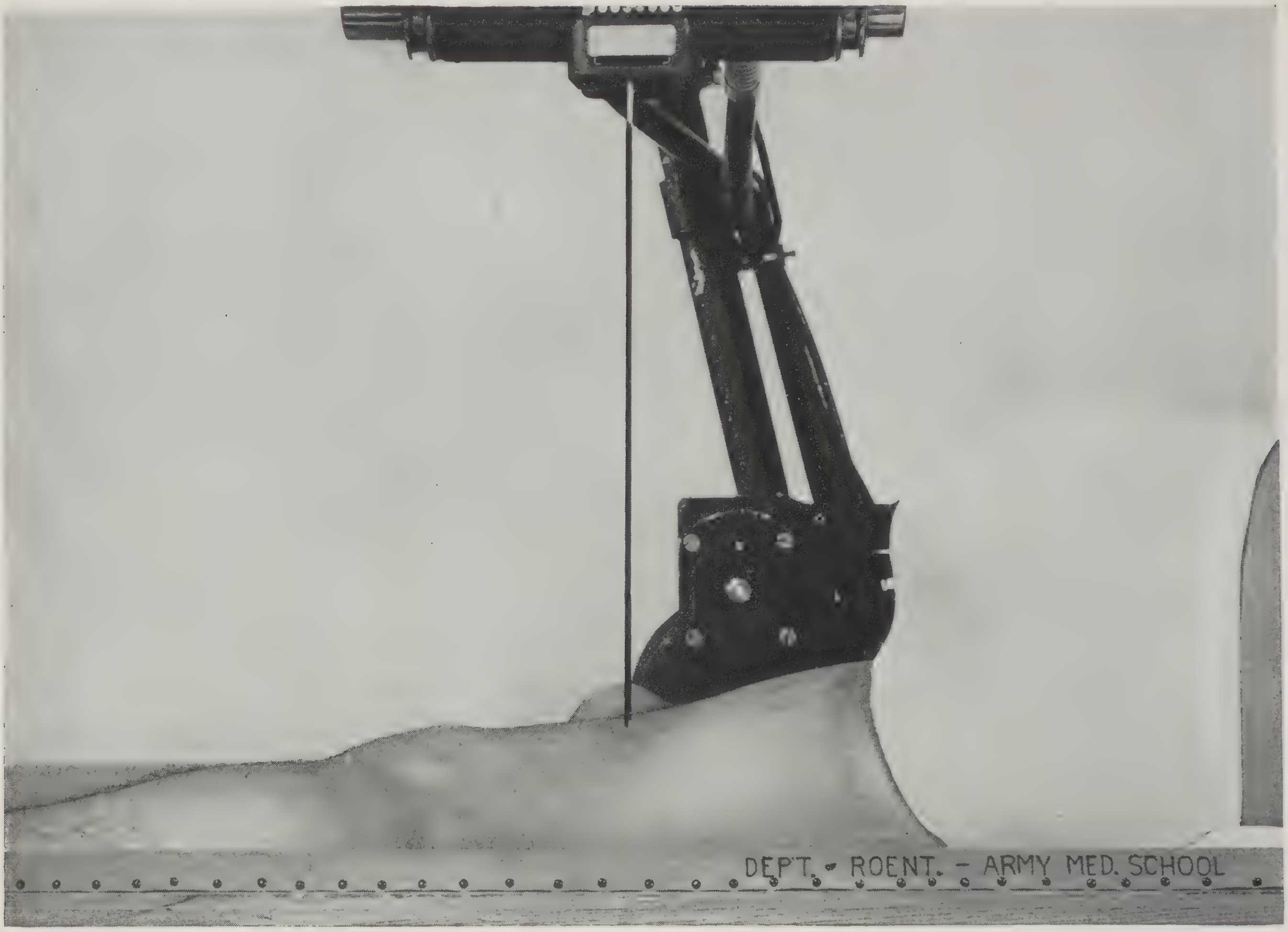
ADDITIONAL: Grid; immobilization if necessary.

VARIATIONS: If site of injury is unknown, hip should be included in film.

DISTANCE: 30″ — Measure through plane at midlength

CMS. THICKNESS		8	9	10	11	12	13	14	15	16	17	18	19	20
VARIABLE KVP	with cardboard holders	68	70	72										
	with medium screens				74	76	78							
	with Army wafer grid							70	72	74	76	78	80	82
MA - SEC		200			8			35						

Fig. 150.—THIGH (femur) LATERAL



ANATOMICAL: Femur, soft tissues.

FILM: 14 x 17 inch, lengthwise.

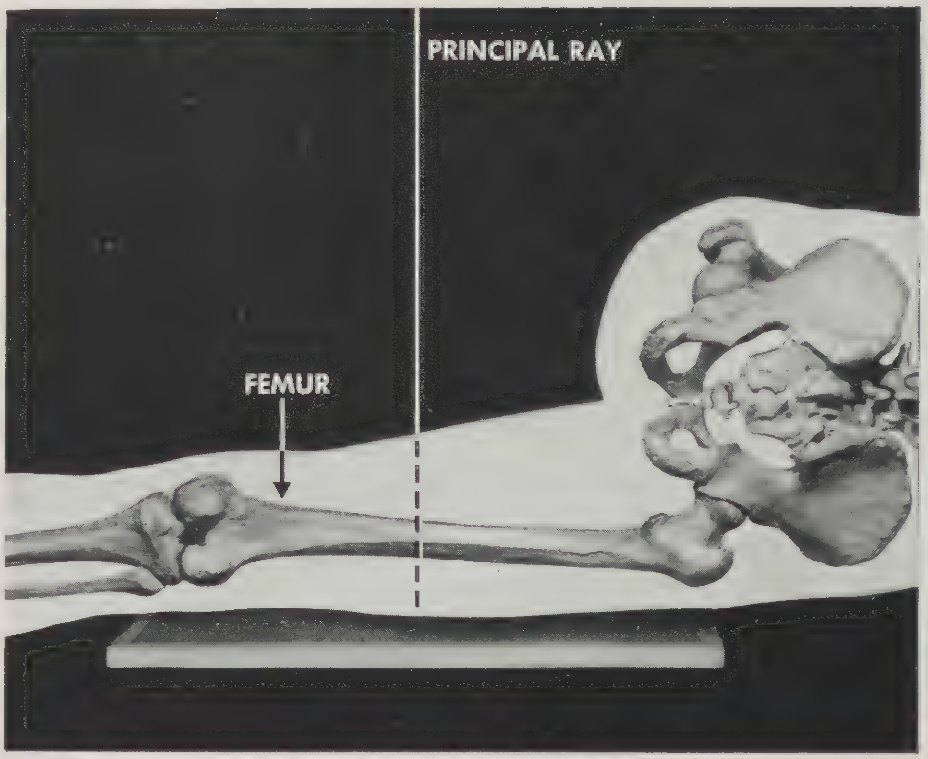
POSITION: Patient laterally recumbent, joint nearer site of injury 7 cm from border of film.

FOCAL SPOT: Align to center of film.

PRECAUTIONS: Extreme flexion of opposite thigh. If the upper portion of femur is being examined, principal ray is directed 15° cephalad to provide clearance of opposite buttock.

ADDITIONAL: Grid; immobilization by sandbags across leg.

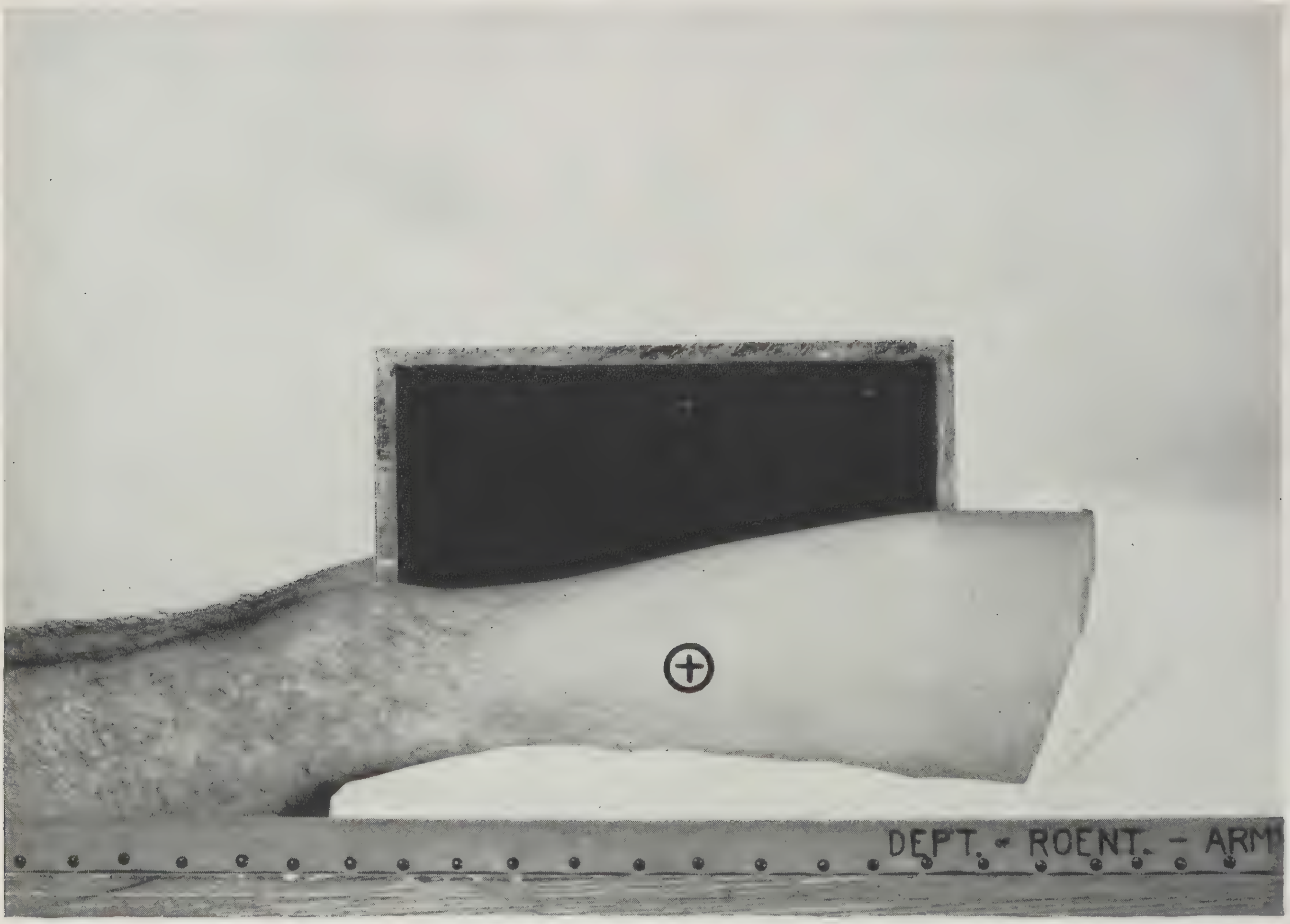
NOTE: This position is often difficult to maintain for patients with severe injuries; it should not be attempted in suspected fractures of the femur.

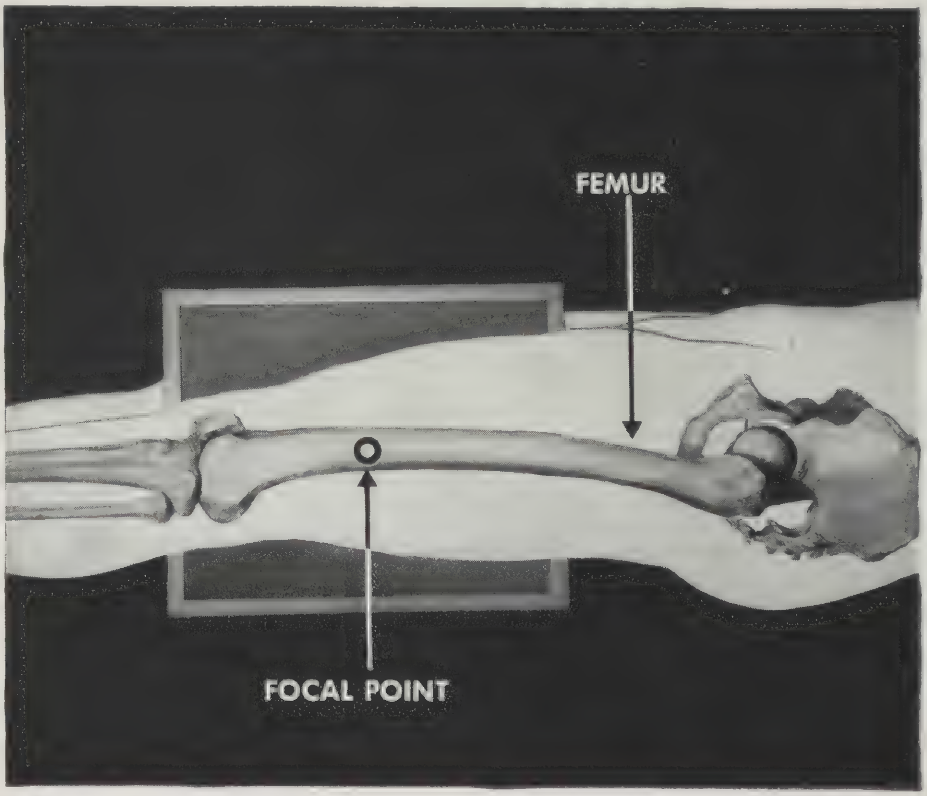


DISTANCE: 30″ — Measure through plane at midlength

CMS. THICKNESS		8	9	10	11	12	13	14	15	16	17	18	19	20
VARIABLE KVP	with cardboard holders	68	70	72										
	with medium screens				74	76	78							
	with Army wafer grid							70	72	74	76	78	80	82
MA - SEC			200			8					35			

Fig. 151.—THIGH, LATERAL (stretcher patient)





ANATOMICAL: Femur and soft tissues.

FILM: 10 x 12 inch, lengthwise and vertical.

POSITION: Patient supine, inner surface of thigh in contact with cassette.

FOCAL SPOT: Align to center of film.

PRECAUTION: Elevation of limb or depression of cassette to insure proper positioning of image on film.

ADDITIONAL: Sandbag over leg; grid advisable.

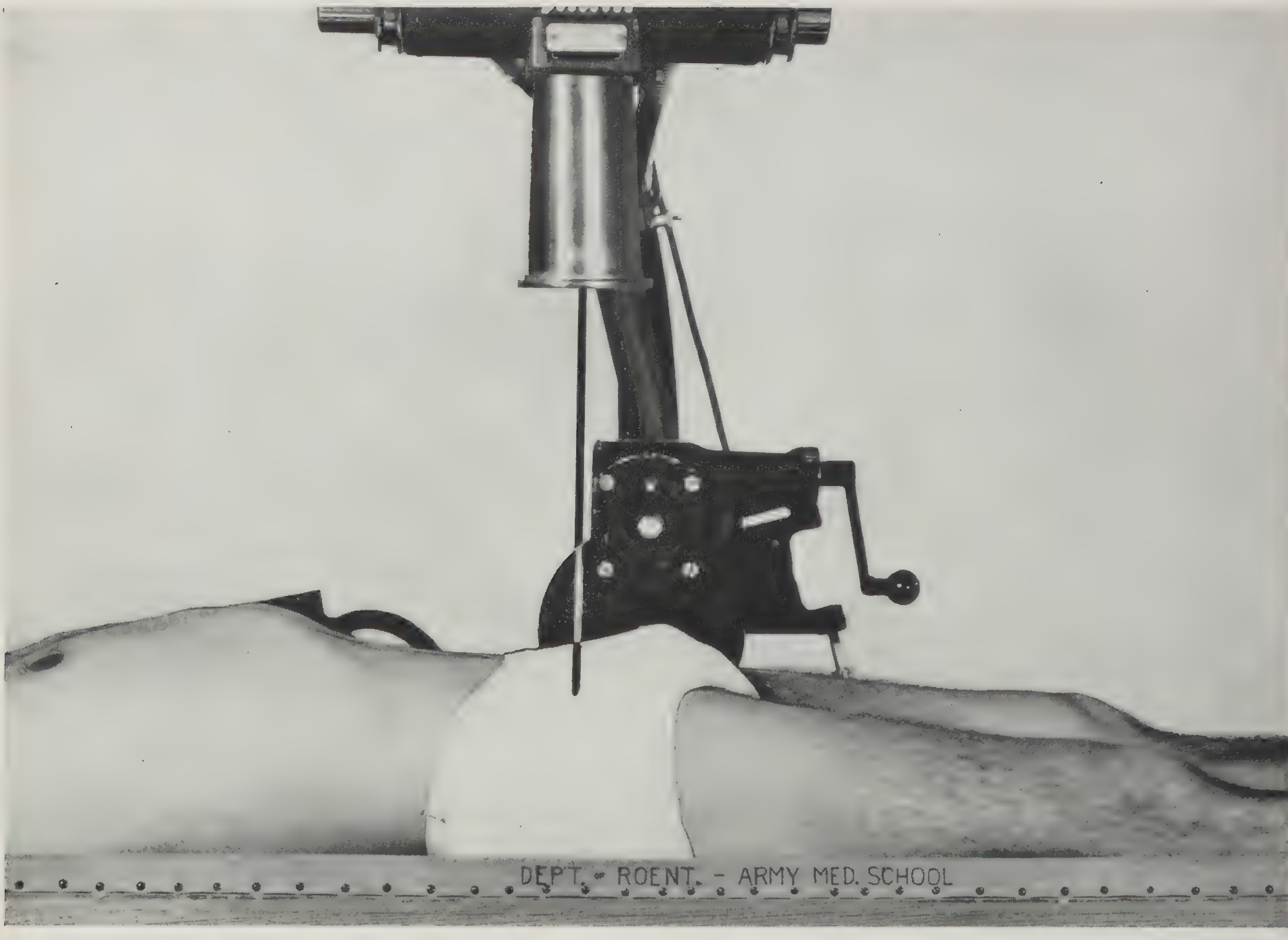
NOTE: This is position of choice in severe injuries to thigh, or in conjunction with anteroposterior view for foreign body localization.

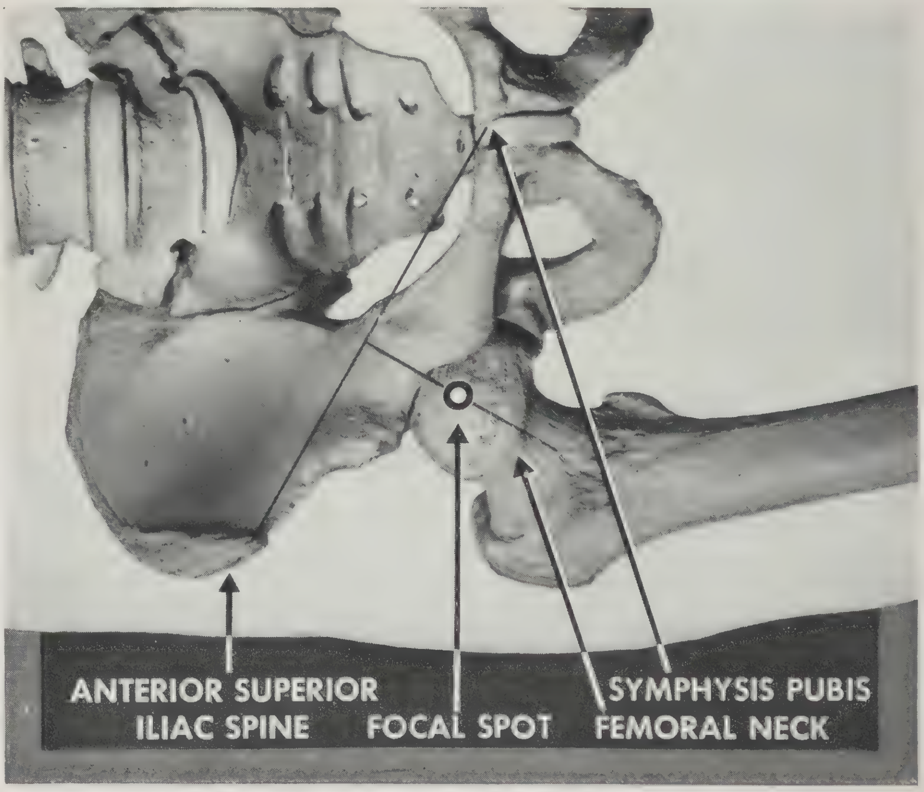
DISTANCE: 30″ Measure through plane at midlength

CMS. THICKNESS	8	9	10	11	12	13	14	15	16	17	18	19	20
VARIABLE KVP with cardboard holders	68	70	72										
VARIABLE KVP with medium screens				74	76	78							
VARIABLE KVP with Army wafer grid							70	72	74	76	78	80	82
MA - SEC		200			8					35			

See lateral thigh.

Fig. 152.—HIP, ANTEROPOSTERIOR





ANATOMICAL: Femoral head, neck, greater trochanter; acetabulum.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient supine, greater trochanter 5 cm. from lateral border.

FOCAL SPOT: Align to point 2 cm. below and 2 cm. lateral to middle of line (inguinal ligament) from the anterosuperior iliac spine to pubic symphysis.

PRECAUTION: Toes upward (slight internal rotation).

ADDITIONAL: Grid and cone. Sandbag immobilization if necessary.

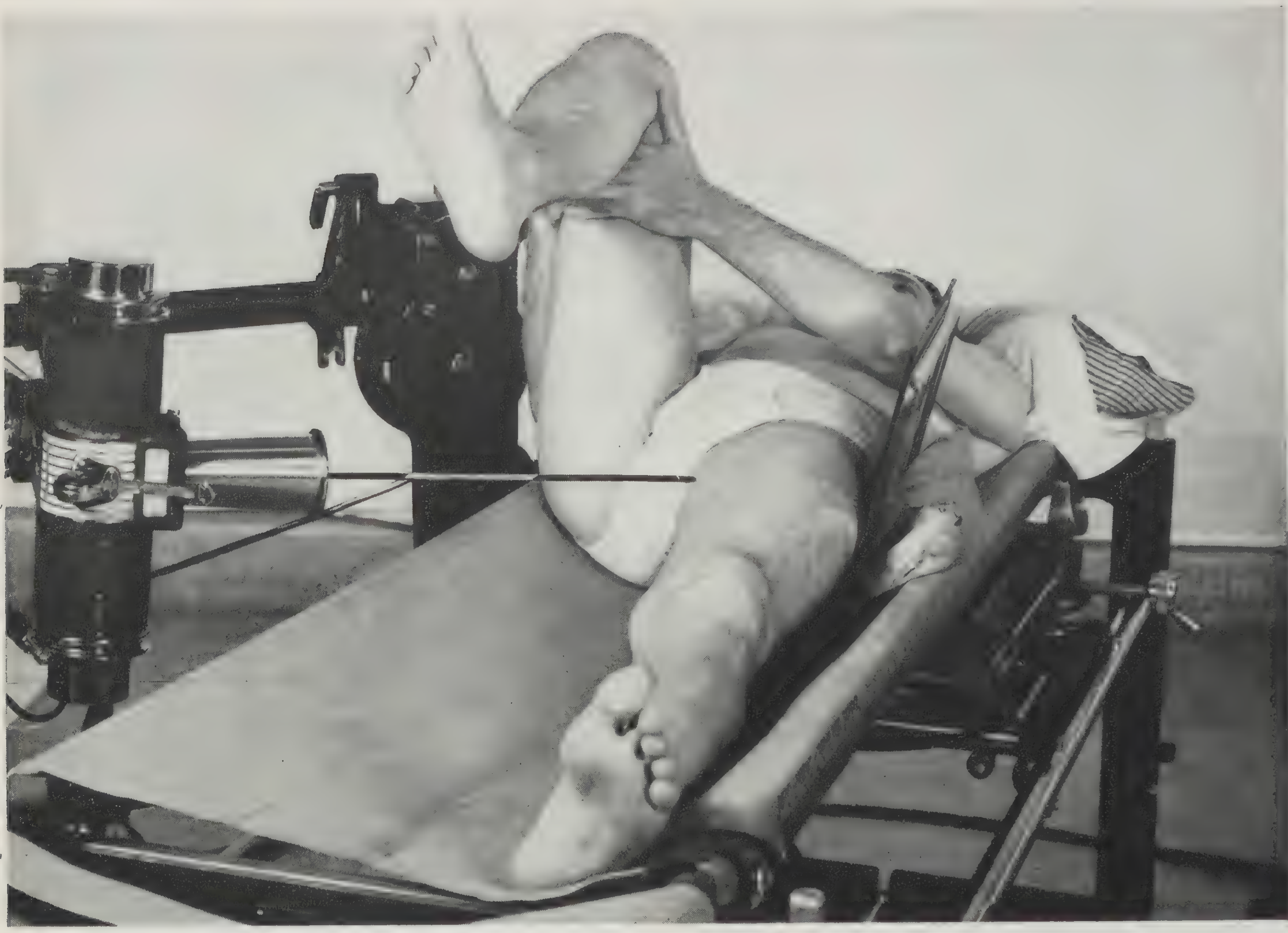
VARIATION: Stereoscopic films frequently requested.

DISTANCE: 30″ — Measure through plane across greater trochanter

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	70	72	74	76	78	70	72	74	76	78	80	70	72	74	76	78	80
MA - SEC				25						50						100		

AUXILIARIES: CONE.

Fig. 153.—FEMUR, NECK, LATERAL



ANATOMICAL: Femoral neck and head, upper third of shaft, acetabulum.

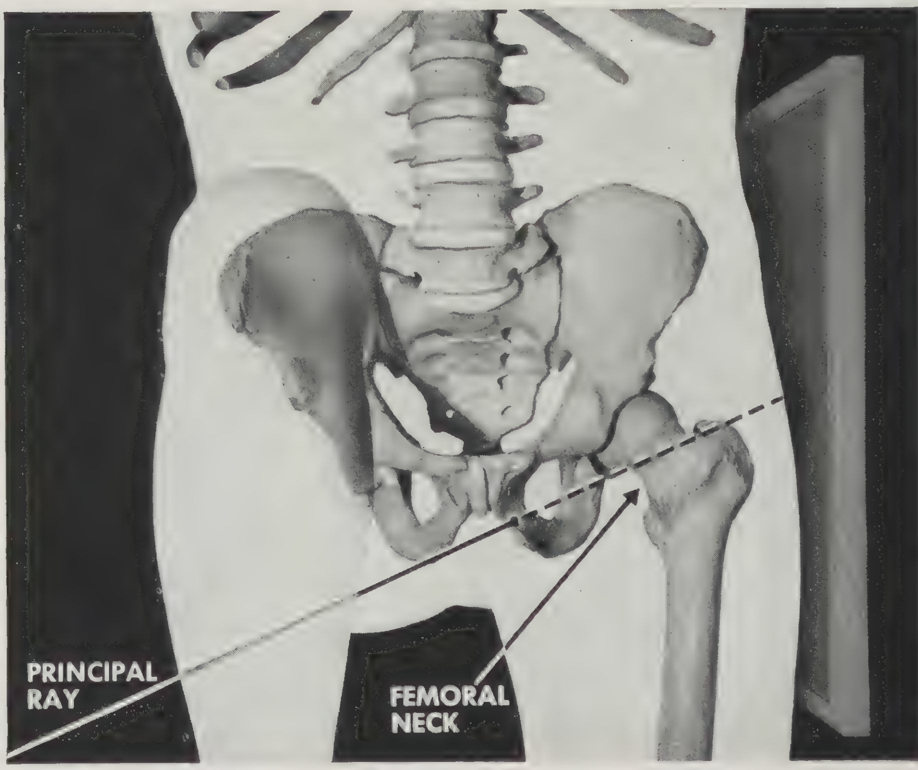
FILM: 10 x 12 inch, lengthwise and vertical.

POSITION: Patient supine, greater trochanter to center of lower half of film, cassette parallel to femur, leg in slight abduction.

FOCAL SPOT: Principal ray directed 30° cephalad and 25° downward—through neck to center of film.

PRECAUTION: Opposite leg flexed and elevated to afford clearance of primary beam; affected hip elevated on sandbag.

ADDITIONAL: Grid and cone.

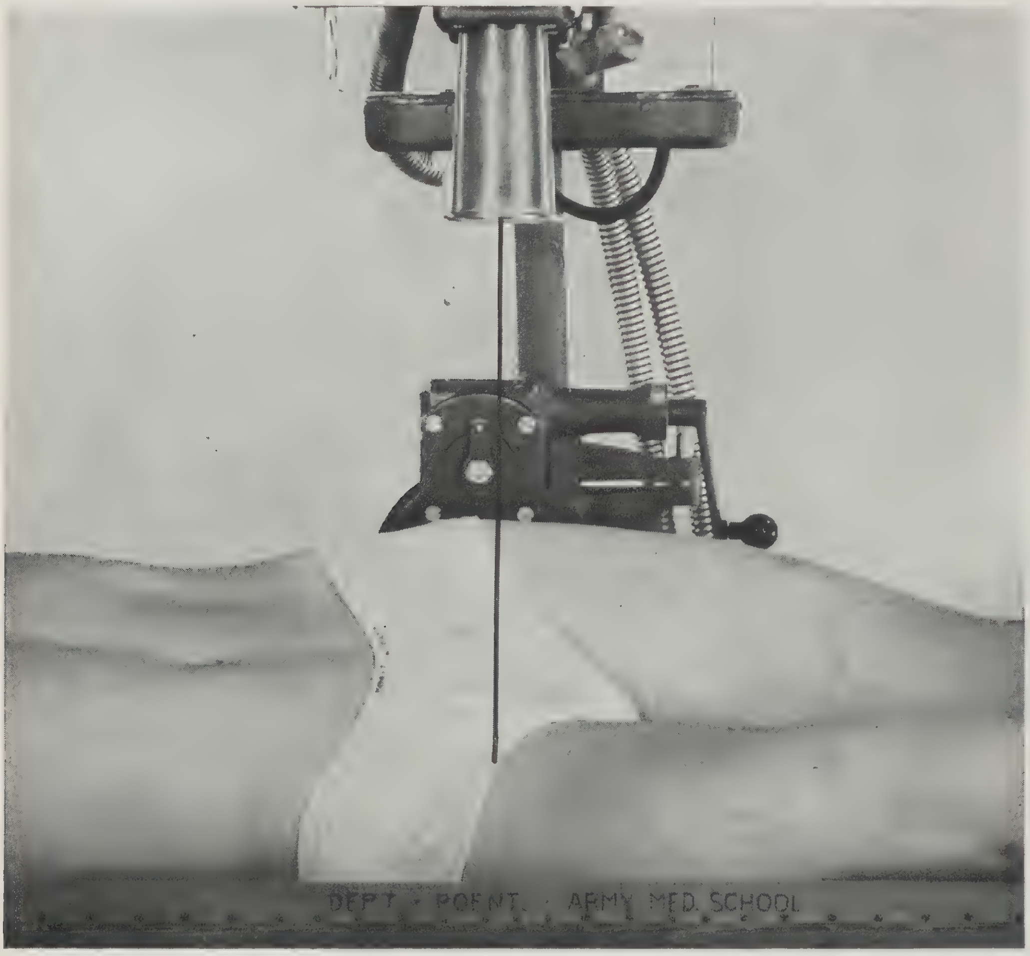


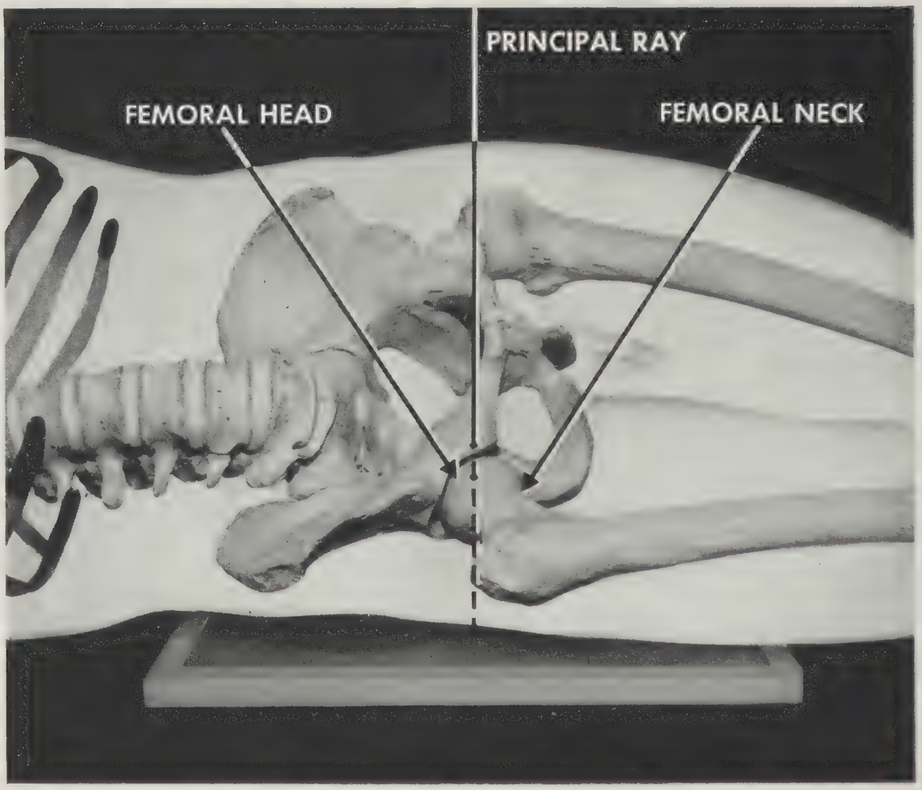
DISTANCE: 30″ Measure through plane of principal ray

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	64	66	68	70	72	74	76	78	70	72	74	76	78	80
MA - SEC		50								100					

AUXILIARIES: CONE or cylinder.

Fig. 154.—HIP, NECK OF FEMUR, OBLIQUE





ANATOMICAL: Femoral neck and head, proximal femur; and acetabulum.

FILM: 10 x 12 inch, lengthwise and oblique.

POSITION: Patient supine; lower extremities abducted and laterally rotated about 30°; film obliquely beneath hip with upper border to level of iliac crest.

FOCAL SPOT: Align vertically to head of femur.

PRECAUTION: Sandbags under thigh.

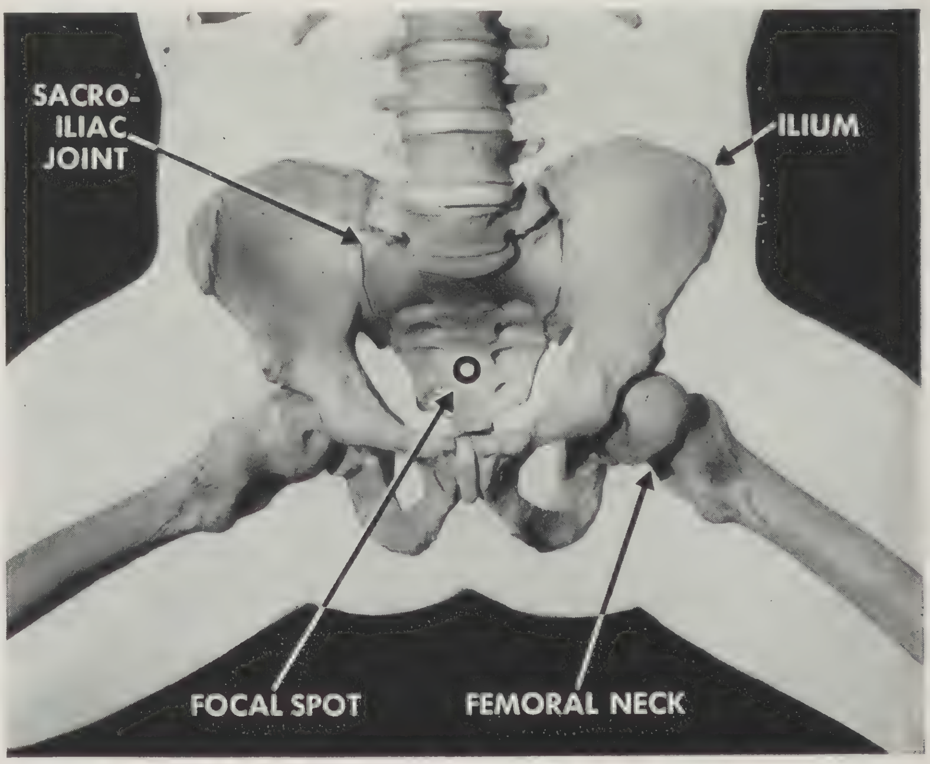
ADDITIONAL: Grid and cone.

DISTANCE: 30″ Measure through plane from directly above femoral head through gluteal region directly posteriorly.

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	64	66	68	70	72	74	76	78	70	72	74	76	78	80
MA - SEC		50								100					

AUXILIARIES: CONE or cylinder.

Fig. 155.—HIP, NECK OF FEMUR, OBLIQUE (frog position)



ANATOMICAL: Pelvic bones, acetabula, femoral heads and necks and soft tissues.

FILM: 14 x 17 inch, widthwise.

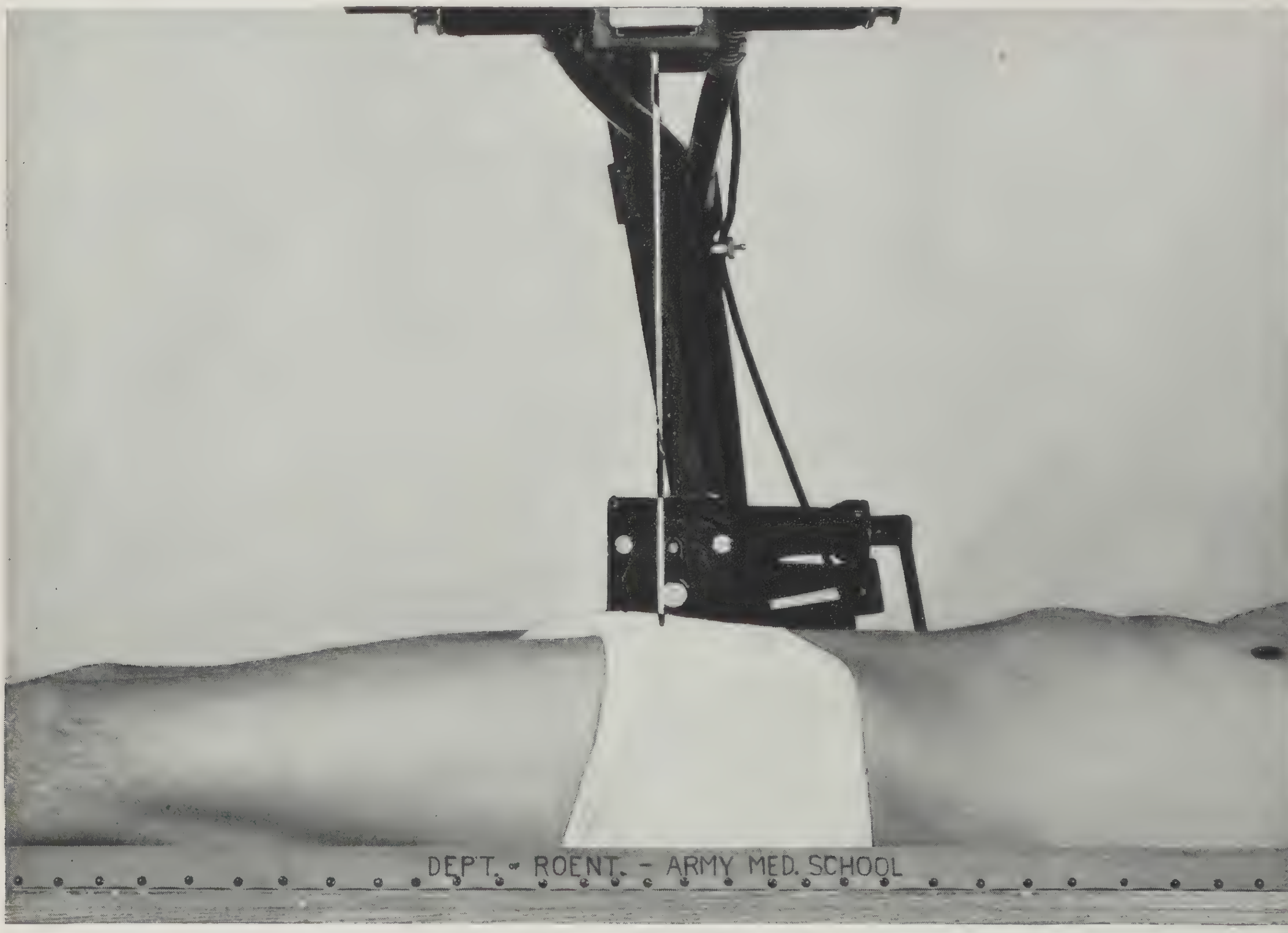
POSITION: Patient supine. Soles of the feet together and knees in flexion and extreme abduction of thighs.

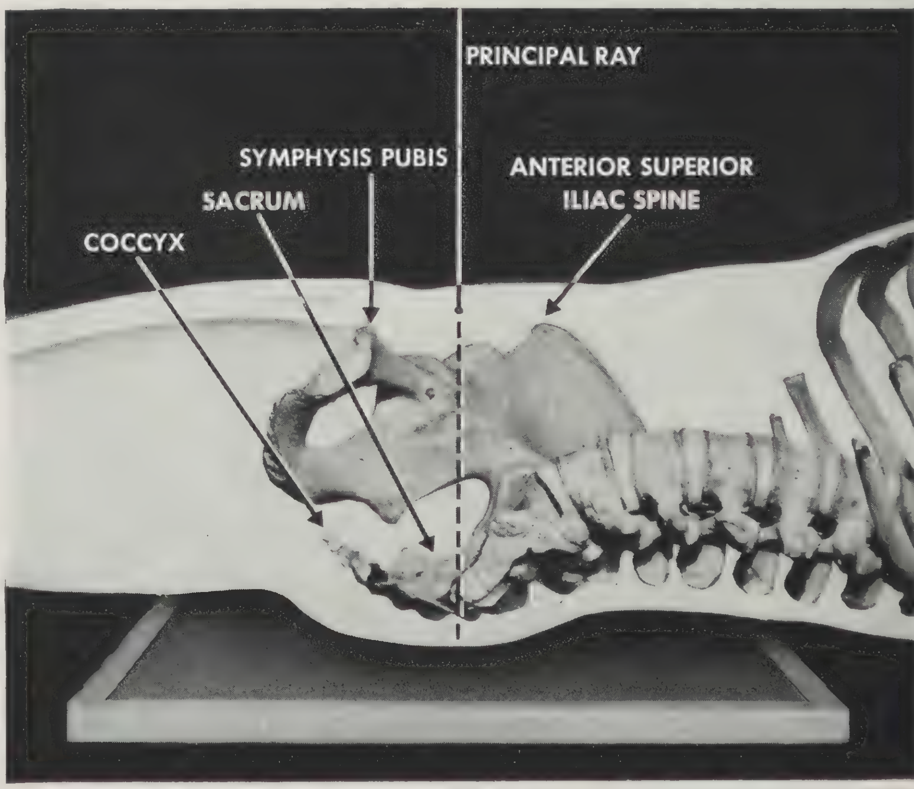
FOCAL SPOT: Align to a point about 5 cm. above pubic symphysis, to center of film.

ADDITIONAL: Grid. Respiration suspended or shallow.

DISTANCE: 30″		Measure through plane midway between symphysis and iliac crests																
CMS. THICKNESS		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	58	60	62														
	with Army wafer grid	.	.	.	64	66	68	70	72	74	76	78	70	72	74	76	78	80
MA - SEC		25			50								100					

Fig. 156.—PELVIS, ANTEROPOSTERIOR





ANATOMICAL: Pelvis, hips and lower lumbar spine.

FILM: 14 x 17 inch, widthwise.

POSITION: Patient supine; iliac crests 5 cm. below upper border of film.

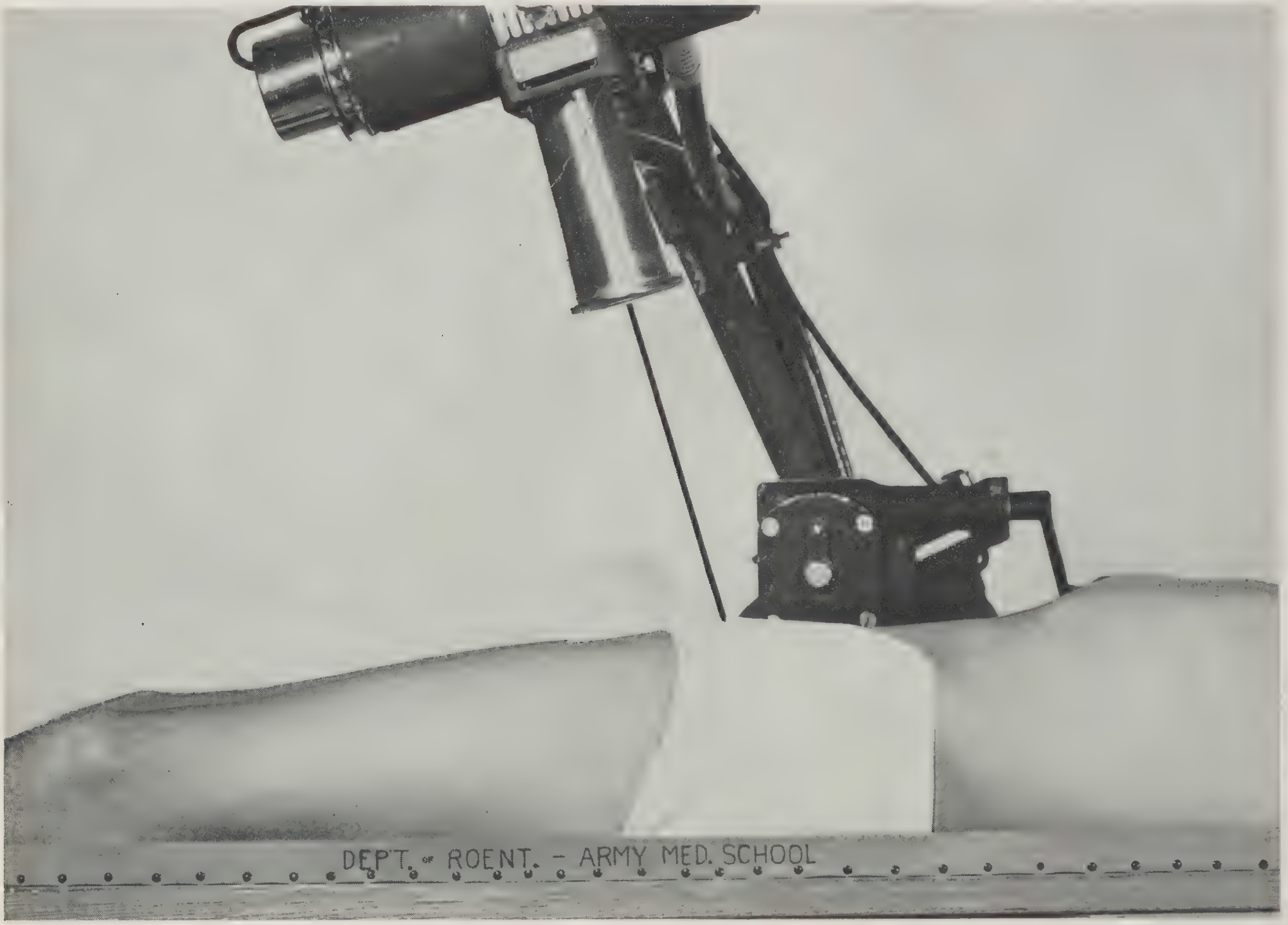
FOCAL SPOT: Align to point midway between anterosuperior iliac spines—to center of film.

PRECAUTION: Straighten patient to midwidth of film; toes up; feet tied.

ADDITIONAL: Grid. Sandbags to lateral surfaces of feet. Stereo pair frequently desired.

DISTANCE: 30″	Measure through plane midway pubic symphysis and crests																	
CMS. THICKNESS		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	58	60	62														
	with Army wafer grid	.	.	.	64	66	68	70	72	74	76	78	70	72	74	76	78	80
MA - SEC		25			50								100					

Fig. 157.—SACRUM, ANTEROPOSTERIOR



ANATOMICAL: Sacrum and sacroiliac articulation.

FILM: 10 x 12 inch, lengthwise.

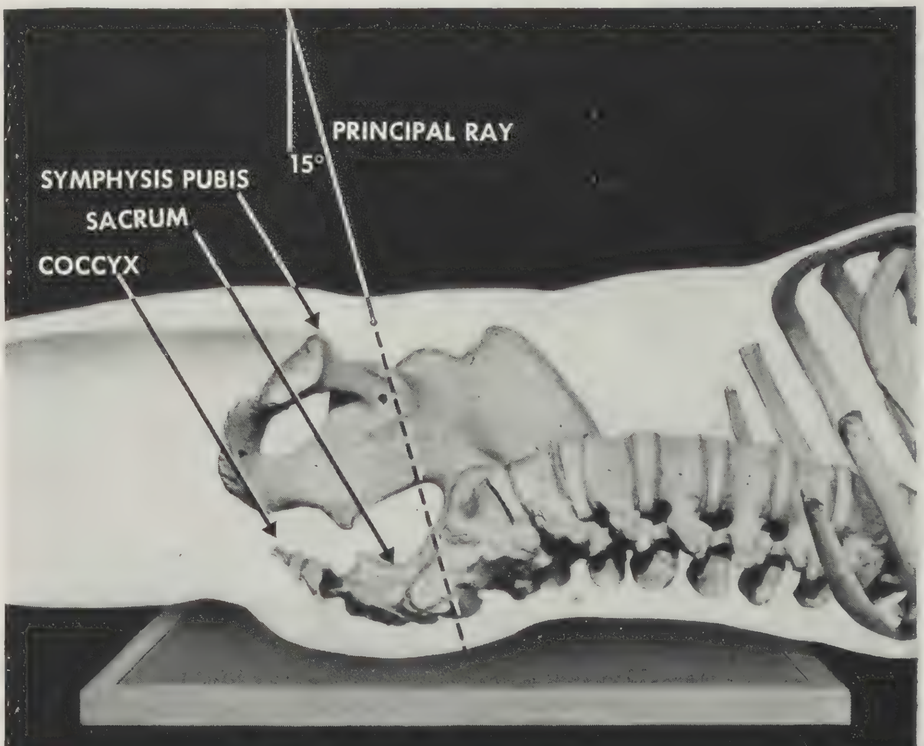
POSITION: Patient supine, iliac crest 5 cm. below upper border of film.

FOCAL SPOT: Align principal ray to point 2 cm. above symphysis pubis, with 15° angulation cephalad—to center of film.

PRECAUTIONS: Pillow under shoulder; sandbag under knees.

ADDITIONAL: Cone and grid.

VARIATIONS: Coccyx is visualized by shifting tube cephalad until principal ray is projected 15° caudad toward pubic symphysis. Lumbosacral articulation is visualized with 10 to 25° angulation of principal ray cephalad. Postero-anterior view of sacrum and entire pelvis is made with patient prone, principal ray angled 10° caudad.

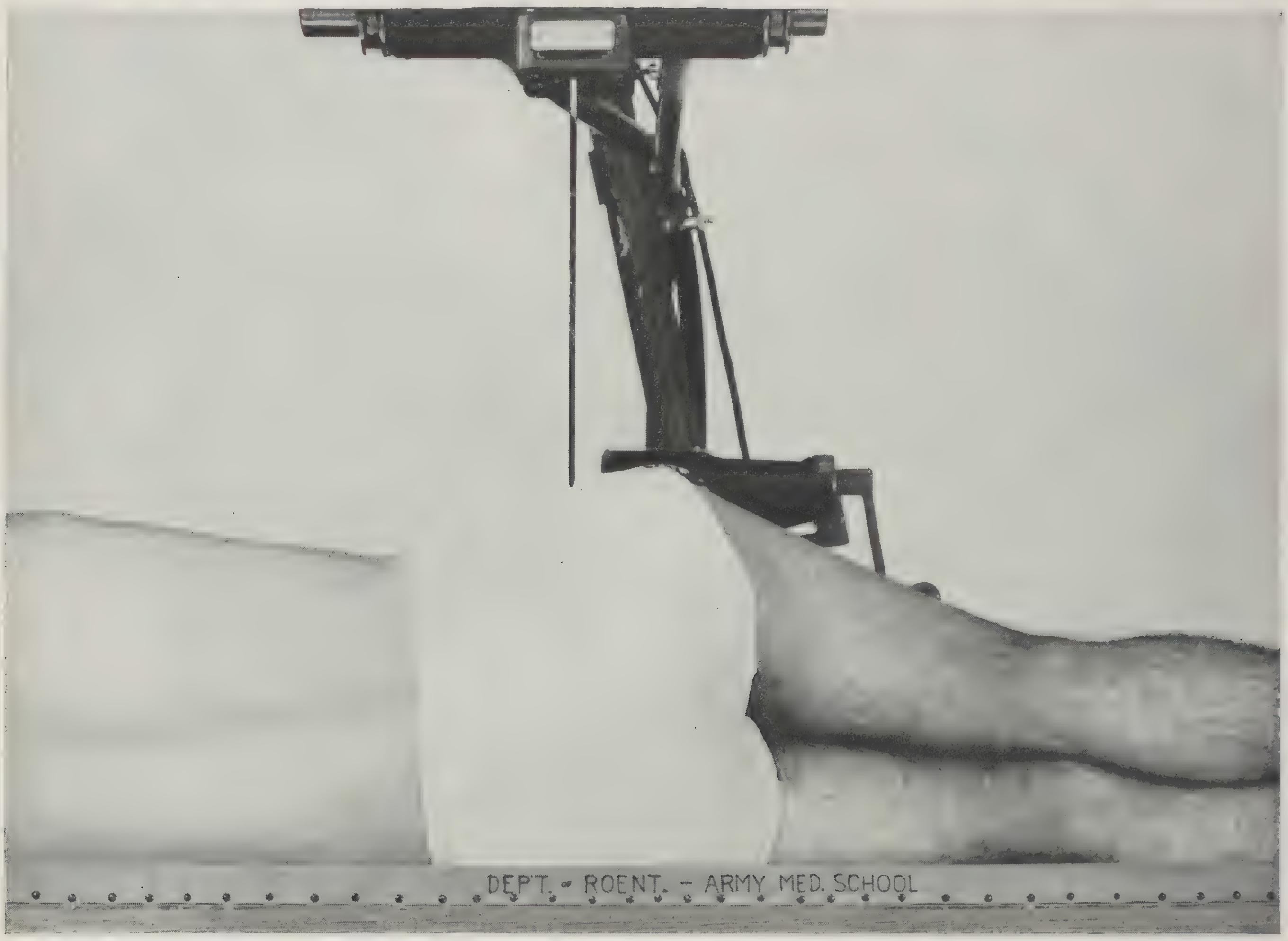


DISTANCE: 30″ — Measure through plane midway between pubic symphysis and crests

CMS. THICKNESS		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	58	60	62															
	with Army wafer grid	.	.	.	64	66	68	70	72	74	76	78	70	72	74	76	78	80	
MA - SEC		25			50								100						

AUXILIARIES: CONE.

Fig. 158.—SACRUM, LATERAL



ANATOMICAL: Lateral view of sacrum and coccyx.

FILM: 10 x 12 inch, lengthwise.

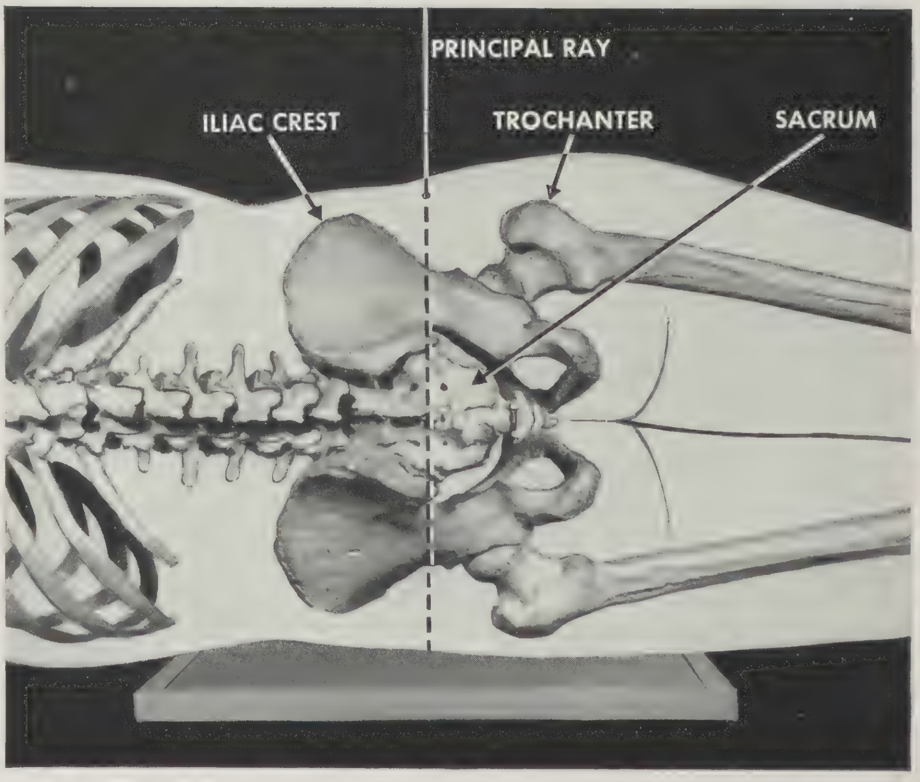
POSITION: Patient laterally recumbent, upper border of film 5 cm. above iliac crest.

FOCAL SPOT: Align to point 5 cm. anterior to skin surface over sacrum, midway between greater trochanter and iliac crest.

PRECAUTION: Iliac crests must be superimposed; thighs slightly flexed; shallow breathing.

ADDITIONAL: Grid. Cone.

VARIATION: Lateral view of 5th lumbar and 1st sacral vertebrae and the articulation between them is visualized better with alignment to 3 cm. below iliac crest.



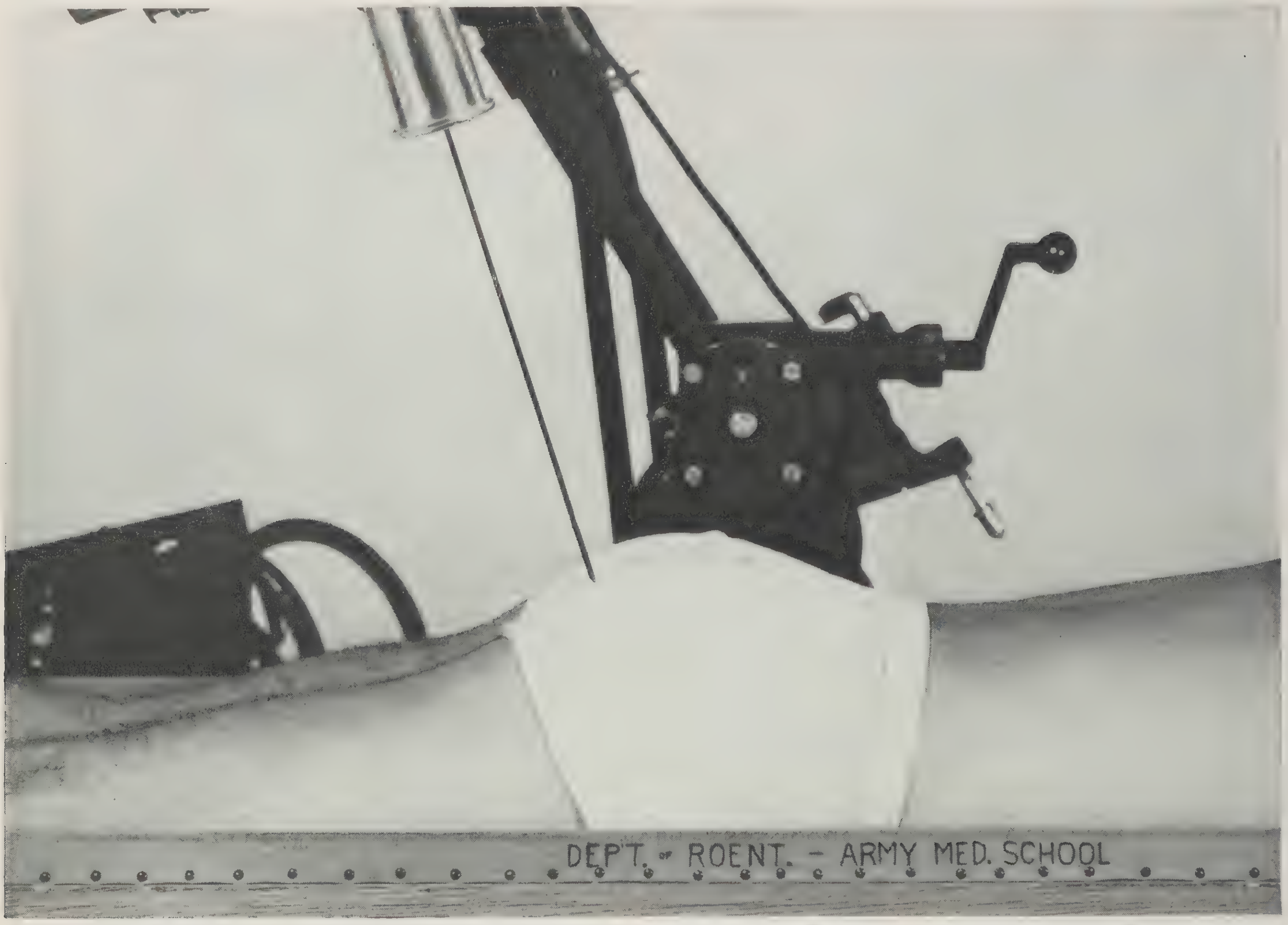
DISTANCE: 30″

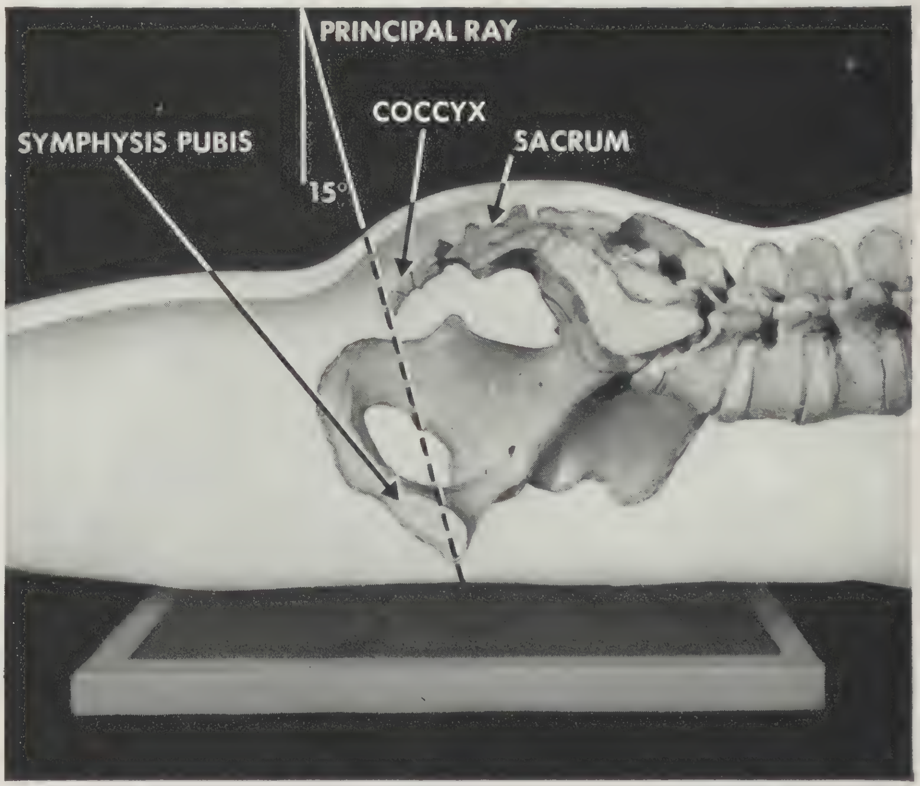
Measure through plane midway trochanters and crests

CMS. THICKNESS		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	72	74	76	78	70	72	74	76	78	80	72	74	76	78	80	82	84	86
MA - SEC			200					400							500				

AUXILIARIES: CONE, grid.

Fig. 159.—SYMPHYSIS PUBIS, POSTERO-ANTERIOR





ANATOMICAL: Symphysis pubis, pubes and superior portions of ischia.

FILM: 10 x 12 inch, widthwise.

POSITION: Patient prone, pubic symphysis about 5 cm. below center of film; trunk straight, feet together.

FOCAL SPOT: Principal ray angled 15° cephalad and aligned to tip of coccyx—to center of film.

PRECAUTION: Avoid rotation of trunk.

ADDITIONAL: Grid, fixation band, if needed.

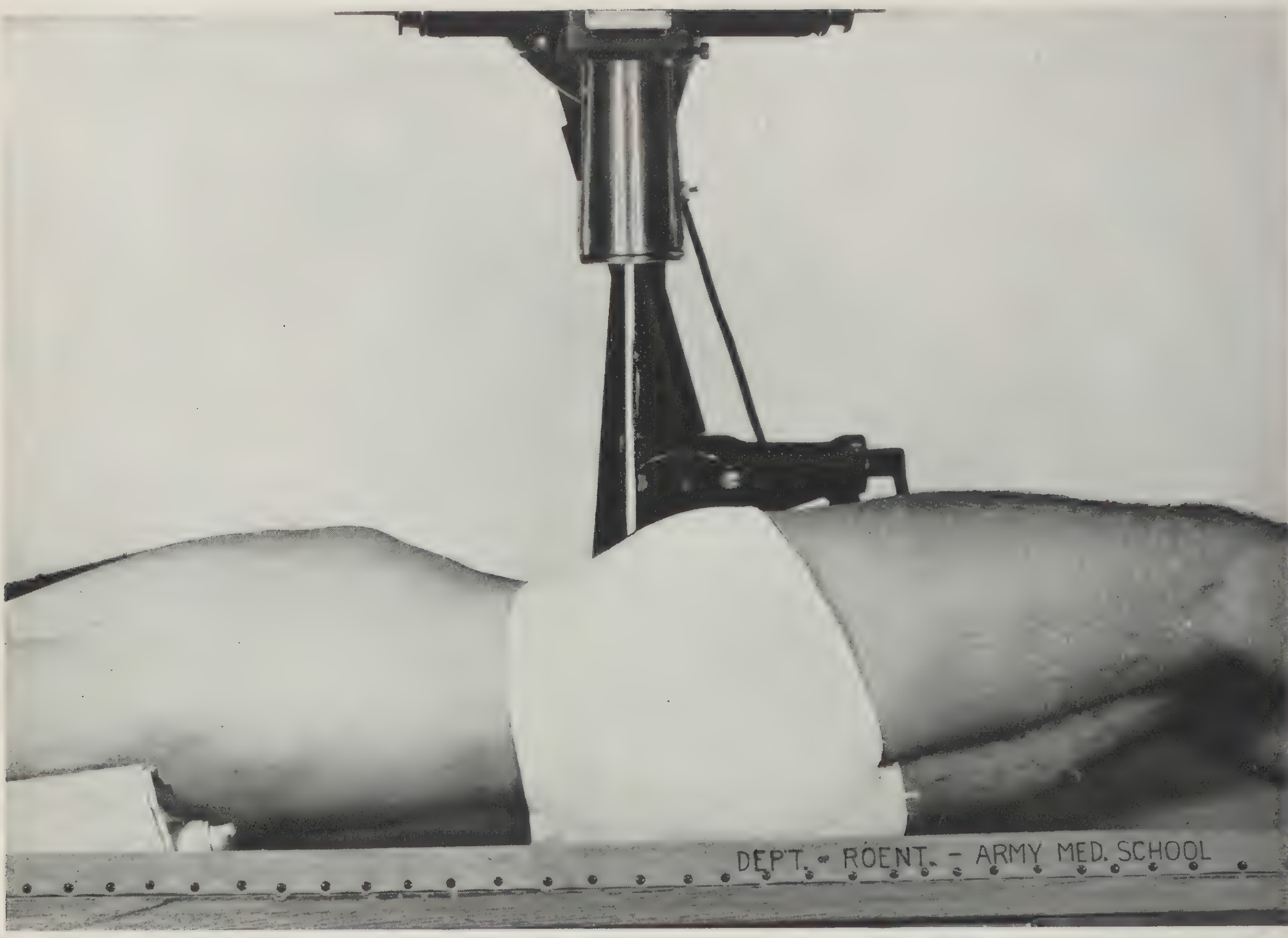
VARIATIONS: Prostatic area may be visualized by use of 10° angulation cephalad.

DISTANCE: 30″ Measure through plane of tip of coccyx and symphysis pubis

CMS. THICKNESS		11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
VARIABLE KVP	with cardboard holders																	
	with medium screens	58	60	62														
	with Army wafer grid				64	66	68	70	72	74	76	78	70	72	74	76	78	80
MA - SEC		30			65								130					

AUXILIARIES: CONE.

Fig. 160.—SACRO-ILIAC, OBLIQUE



ANATOMICAL: Sacro-iliac articulation.

FILM: 10 x 12 inch, lengthwise.

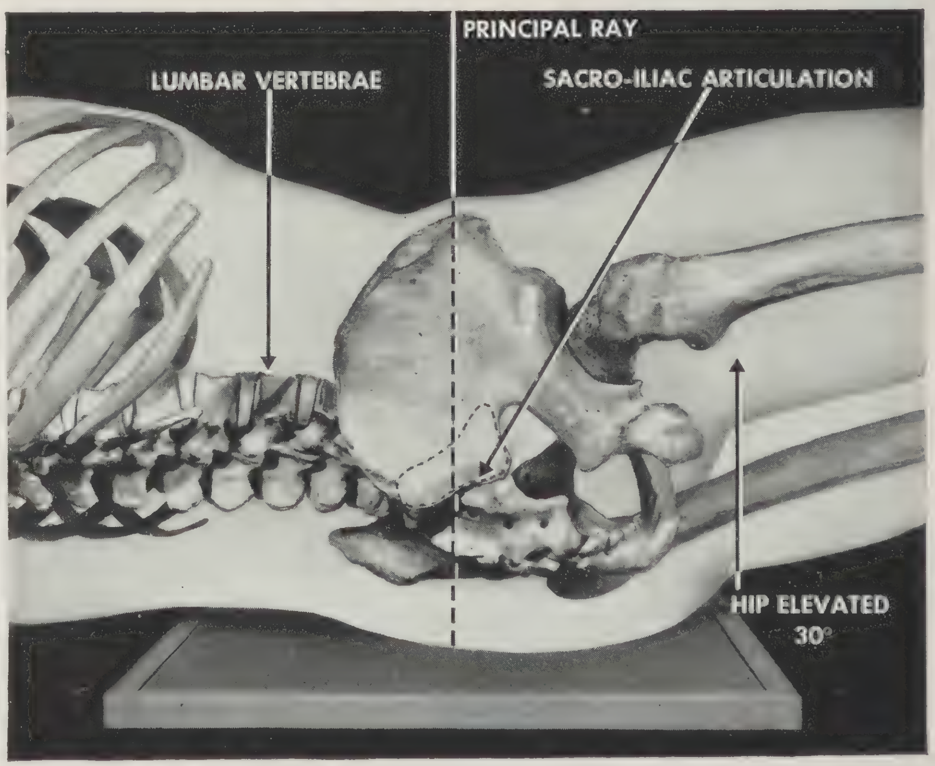
POSITION: Patient supine, with side to be roentgenographed elevated 30°. Posterior iliac spine to center of film.

FOCAL SPOT: Align to point 2 cm. cephalad and 2 cm. medial to anterior superior spine of elevated side.

PRECAUTION: Support rotation by sandbags under loin and thigh of side under study.

ADDITIONAL: Cone and grid.

VARIATION: Oblique view of bladder obtained with same position.

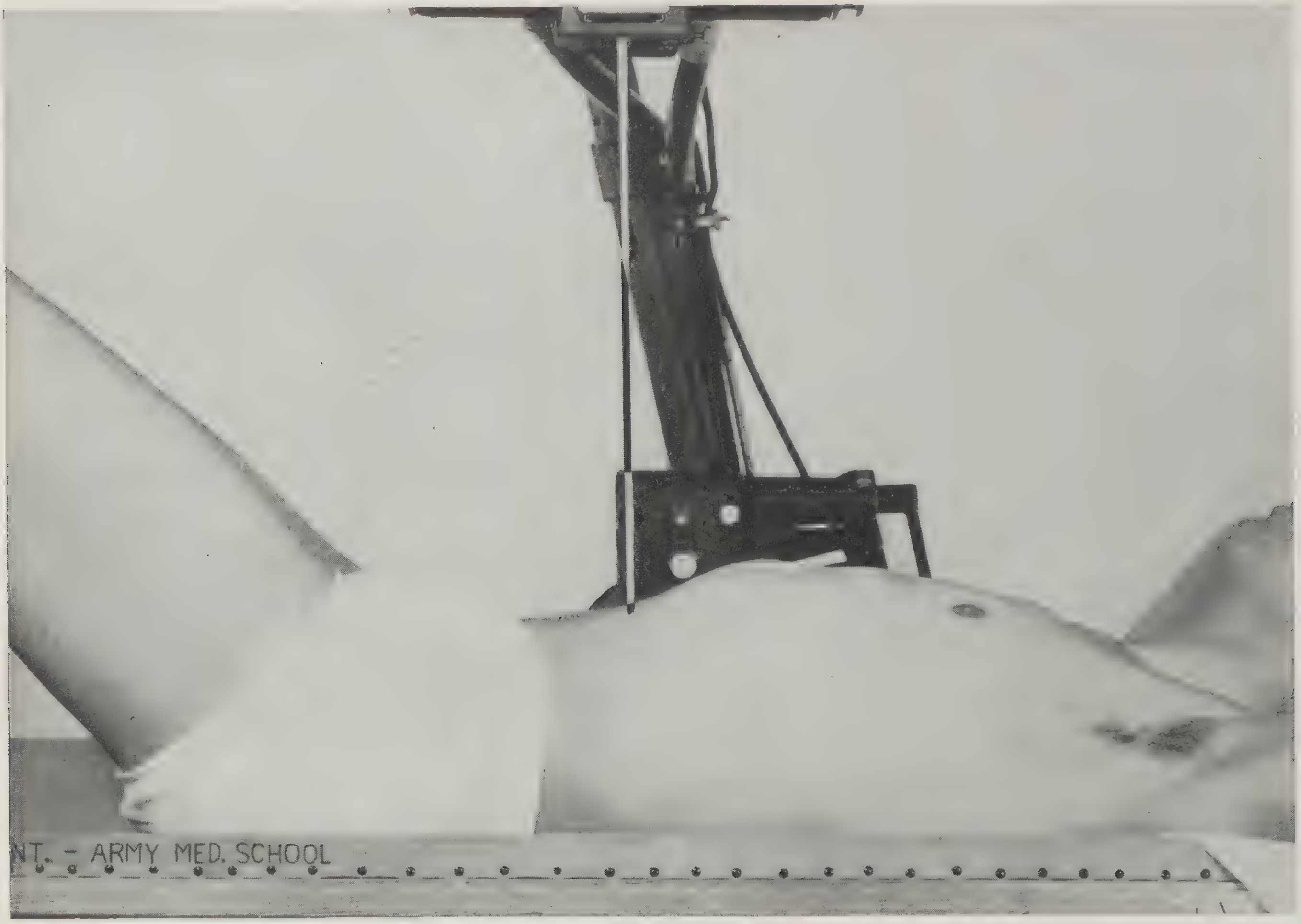


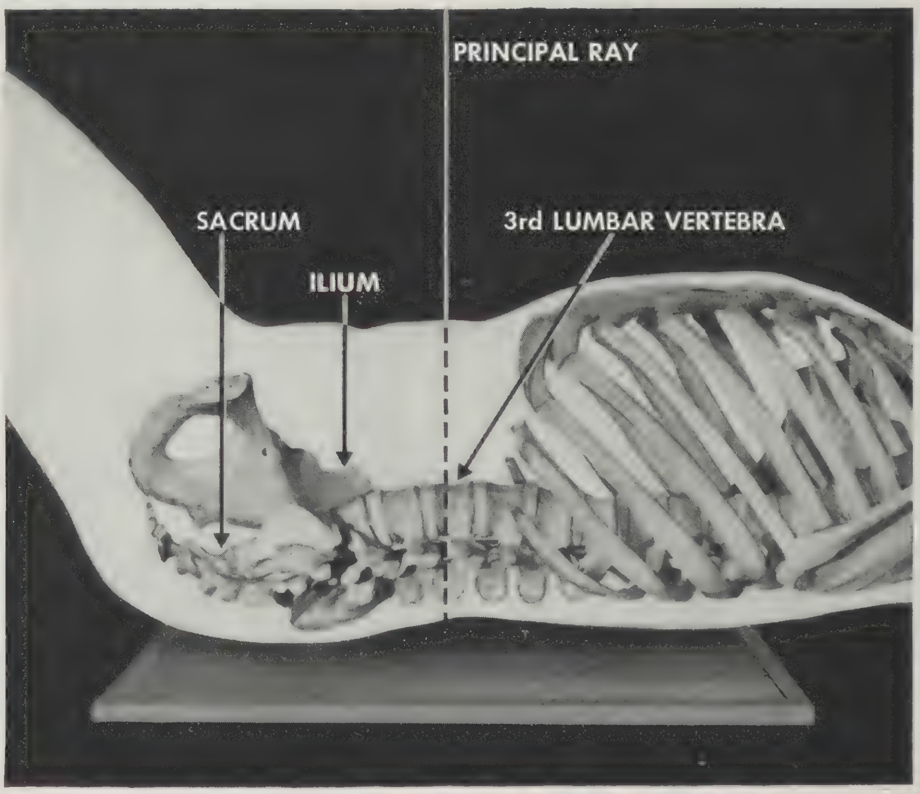
DISTANCE: 30″ Measure through oblique plane of anterior superior iliac spine and posterior superior iliac spine.

CMS. THICKNESS		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
VARIABLE KVP	with cardboard holders																	
	with medium screens																	
	with Army wafer grid	68	70	72	74	76	78	80	72	74	76	78	80	72	74	76	78	80
MA - SEC					70						140					280		

AUXILIARIES: CONE.

Fig. 161.—LUMBAR SPINE, ANTEROPOSTERIOR





ANATOMICAL: Lumbar vertebrae and interspaces; soft tissues.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient supine, crests of iliac to midlength of film.

FOCAL SPOT: Align to center of film.

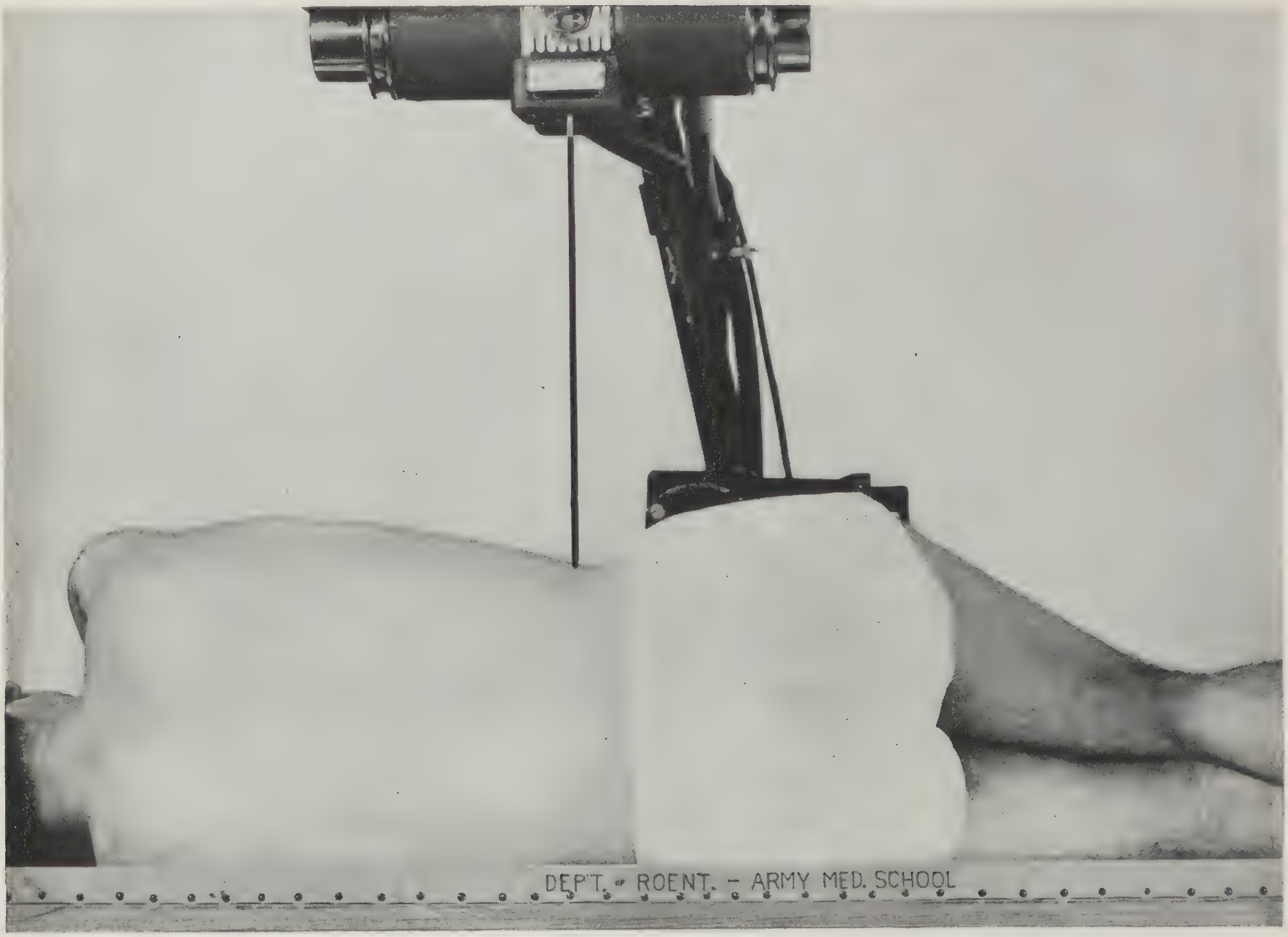
PRECAUTION: Straighten patient to midwidth of film; flatten lordotic curvature (head on pillows; knees raised and flexed).

ADDITIONAL: Grid. Shallow breathing.

DISTANCE: 30″ — Measure through plane of iliac crests

CMS. THICKNESS		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders																
	with medium screens																
	with Army wafer grid	70	72	74	76	68	70	72	74	76	78	80	72	74	76	78	80
MA - SEC			38						75						150		

Fig. 162.—LUMBAR SPINE, LATERAL



ANATOMICAL: Lumbar vertebrae and interspaces; soft tissues.

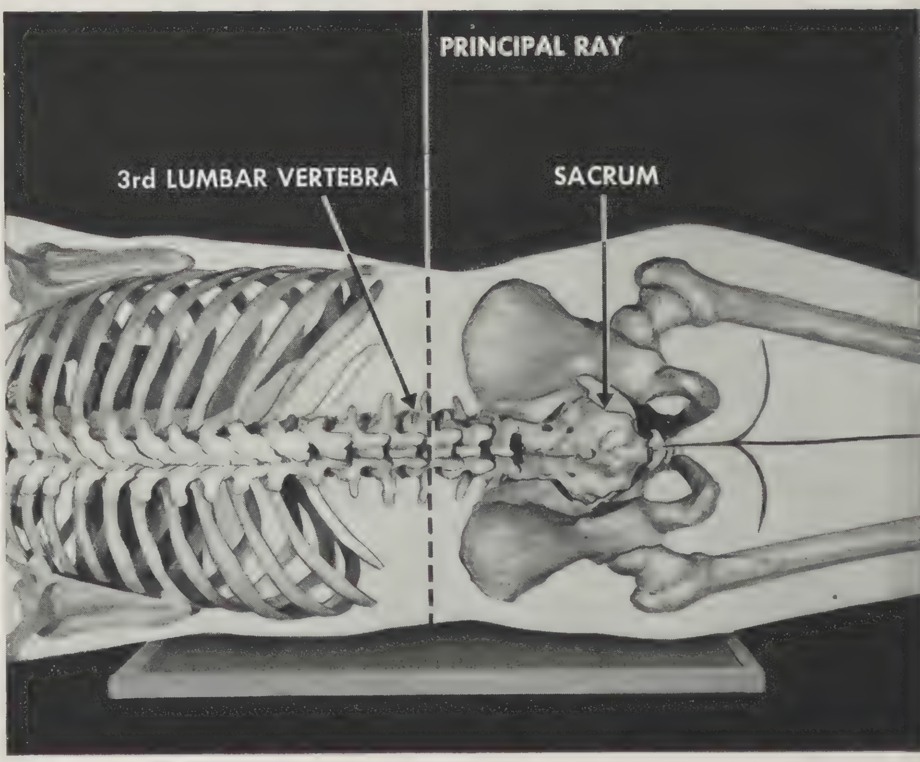
FILM: 14 x 17 inch, lengthwise.

POSITION: Patient laterally recumbent, iliac crests superimposed, axis of spine parallel to and in midwidth of film. Iliac crests at midlength of film.

FOCAL SPOT: Align to 5 cm. above iliac crests and 8 cm. anterior to skin of back.

PRECAUTION: Knees flexed. Arms extended.

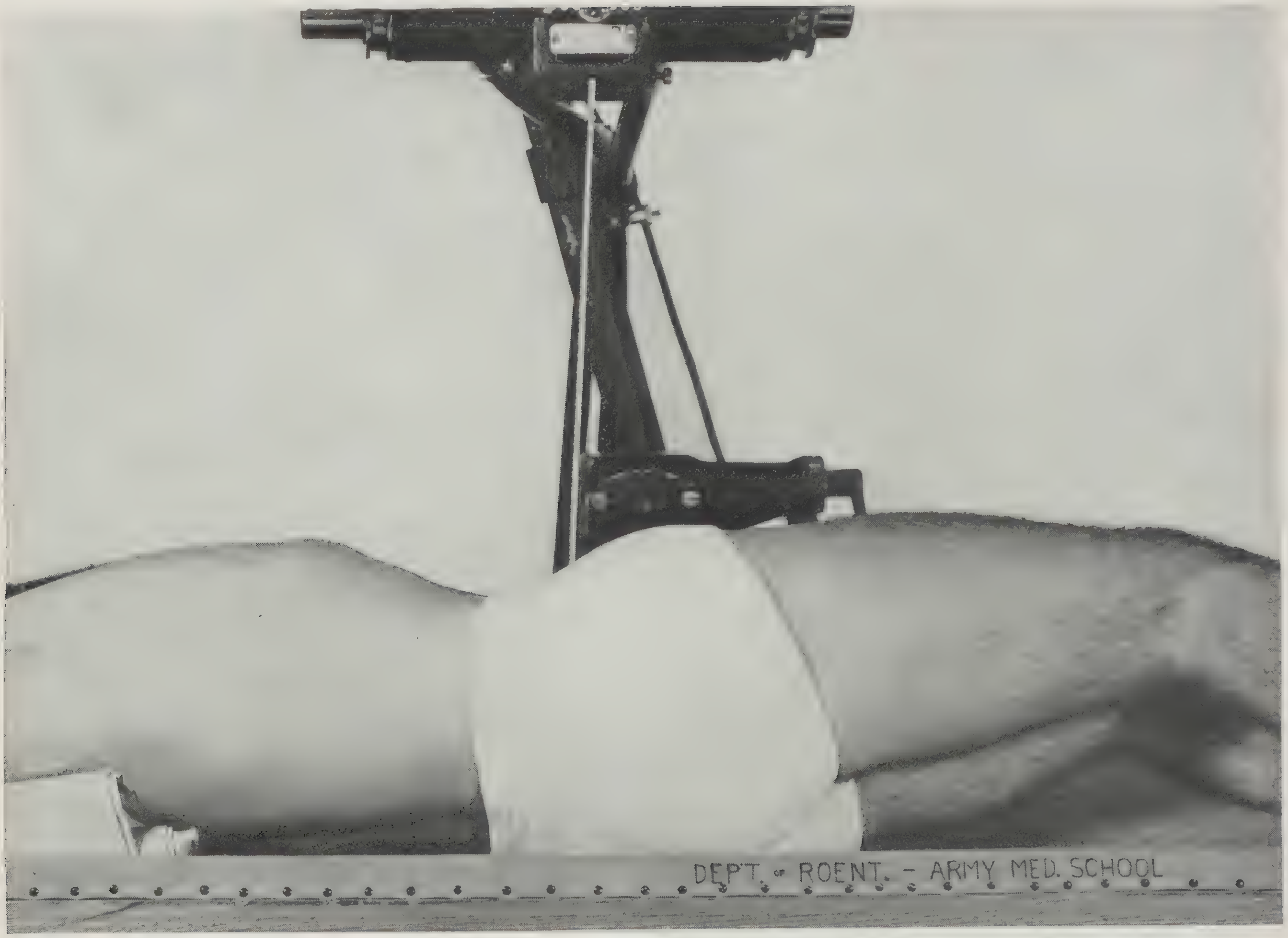
ADDITIONAL: Grid; fixation or other immobilization. It may be necessary to make two successive exposures without moving the patient or film to avoid overloading the tube; for sacro-iliac region, make ordinary exposure, apply cone and add 25 per cent ma-sec.

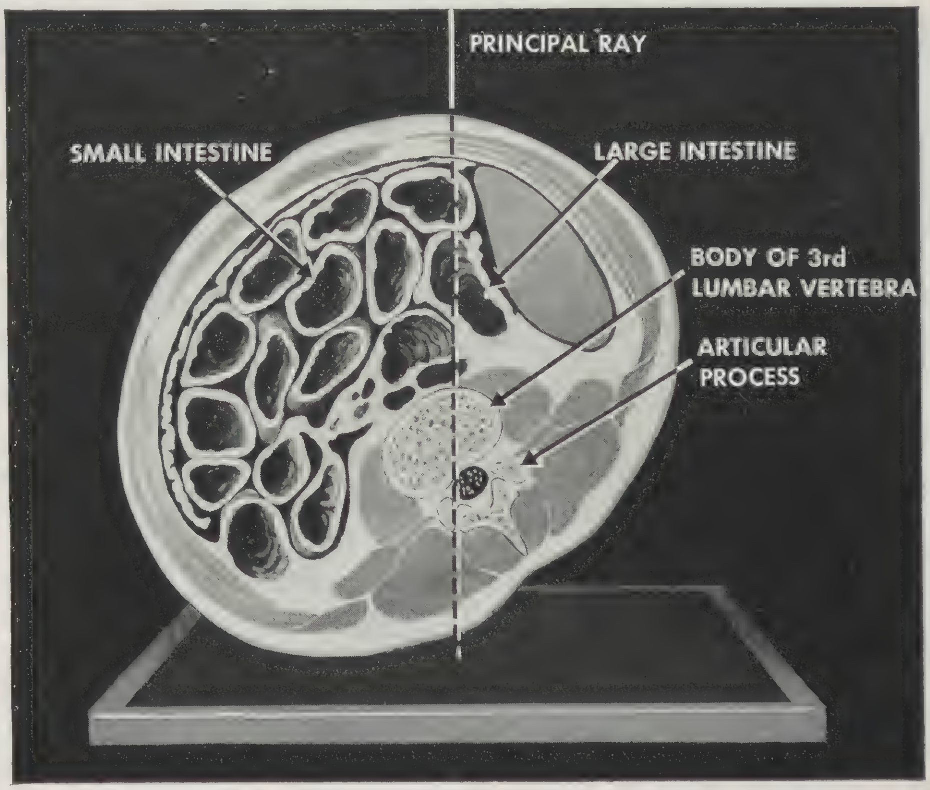


DISTANCE: 30″ — Measure through plane across iliac crests

CMS. THICKNESS		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	74	76	78	80	72	74	76	78	80	82	84	76	78	80	82	84
MA - SEC		150				300							450				

Fig. 163.—LUMBAR SPINE, OBLIQUE





ANATOMICAL: Apophyseal joints, side of rotation.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient supine with 40 to 45° rotation toward side to be studied. Lower iliac crest at midlength of film.

FOCAL SPOT: Align to a point 10 to 14 cm. medial to the anterior-superior iliac spine of the elevated side to center of film.

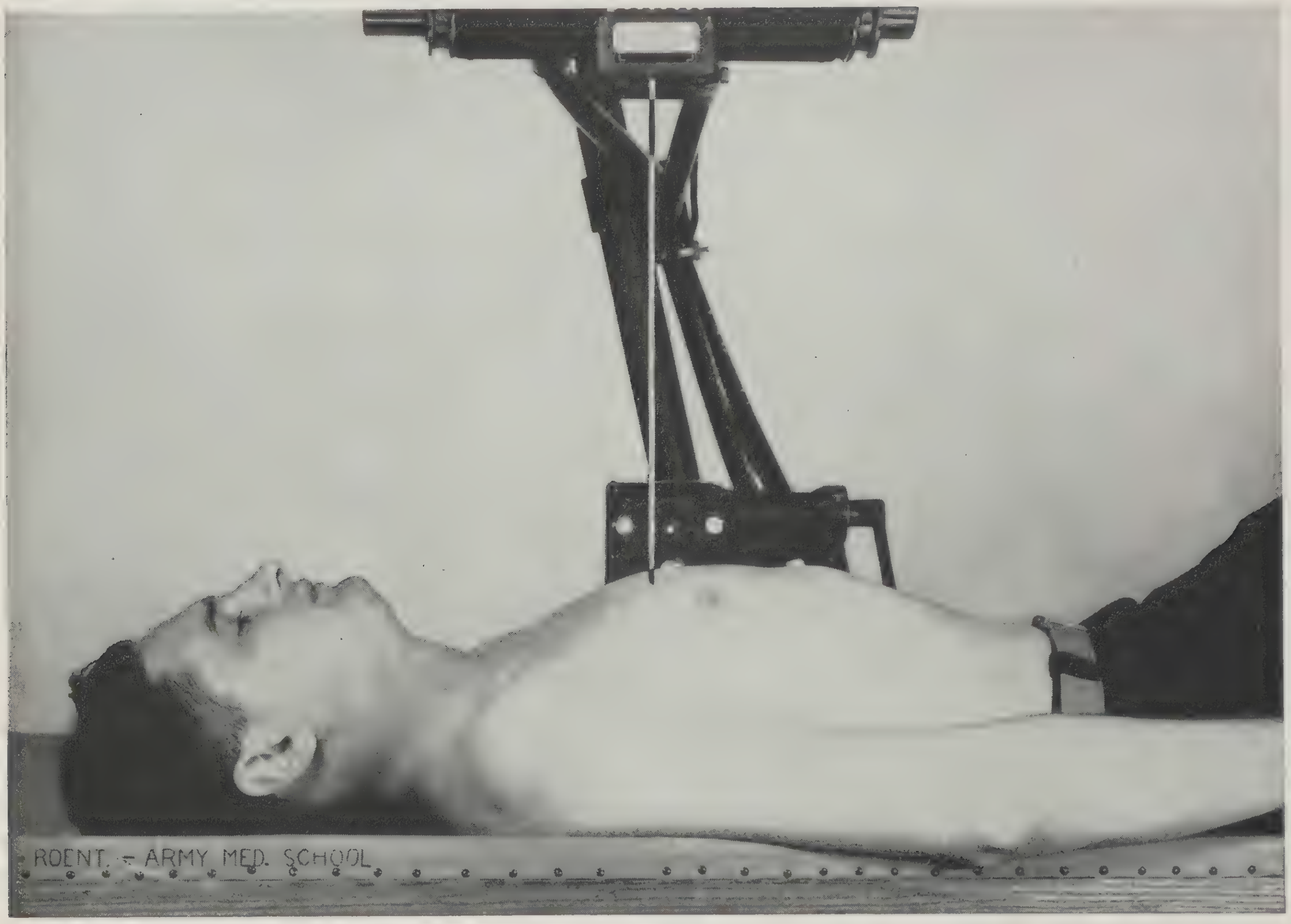
PRECAUTION: Patient aligned to midwidth of film. Knees slightly flexed, sandbag under shoulder and thigh to secure necessary rotation and immobilization. Shallow breathing.

ADDITIONAL: Grid.

DISTANCE: 30″ — Measure through path of principal ray at level of crests

CMS. THICKNESS	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
VARIABLE KVP with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
VARIABLE KVP with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
VARIABLE KVP with Army wafer grid	66	68	70	72	74	76	78	80	82	84	76	78	80	82	84	76	78
MA - SEC					120								244			480	

Fig. 164.—THORACIC SPINE, ANTEROPOSTERIOR



ANATOMICAL: Thoracic vertebrae; paraspinal soft tissues.

FILM: 14 x 17 inch, lengthwise.

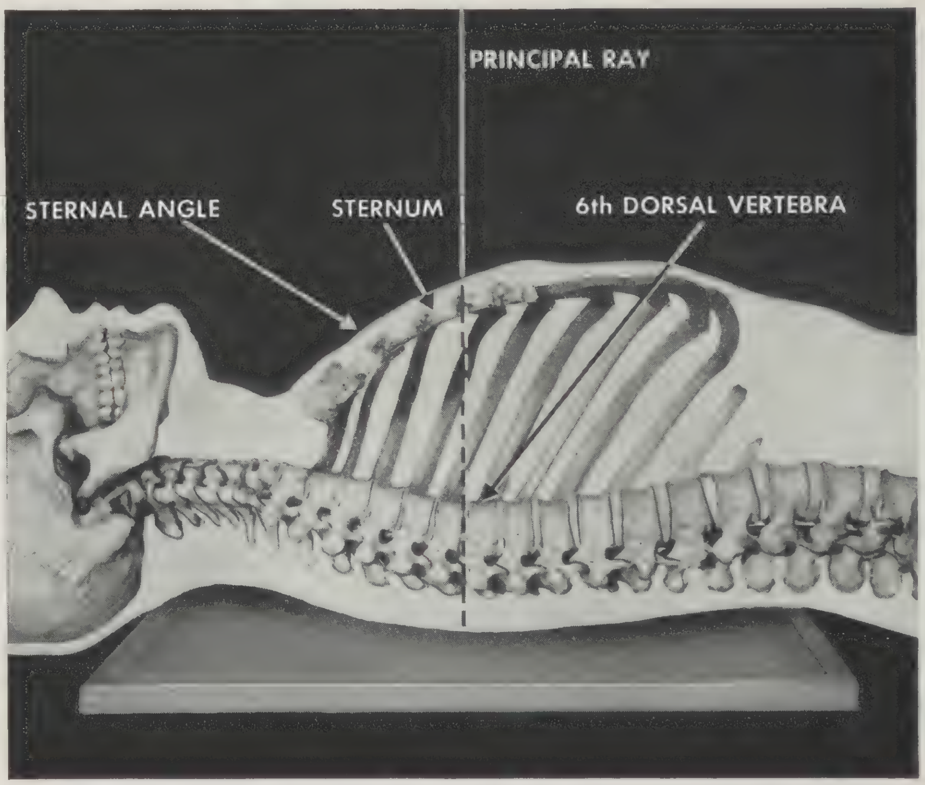
POSITION: Patient supine, spine at midwidth of film, midsagittal plane perpendicular to film, plane of acromial processes 5 cm. below upper border of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Depress shoulders; shallow breathing or suspended respiration.

ADDITIONAL: Grid.

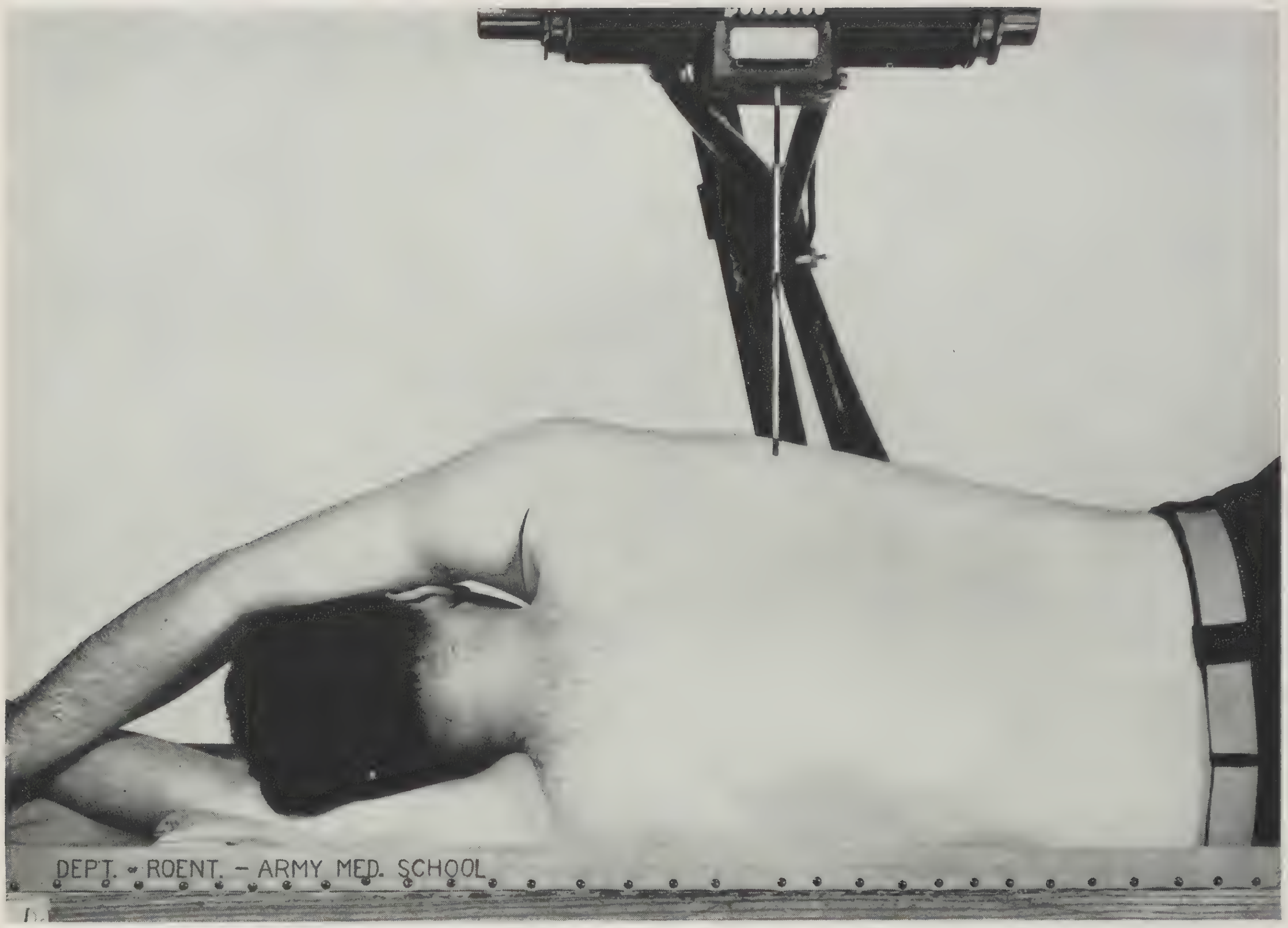
VARIATION: Upper three or four vertebrae may be demonstrated better by less exposure, a 10 x 12 inch cassette being used.

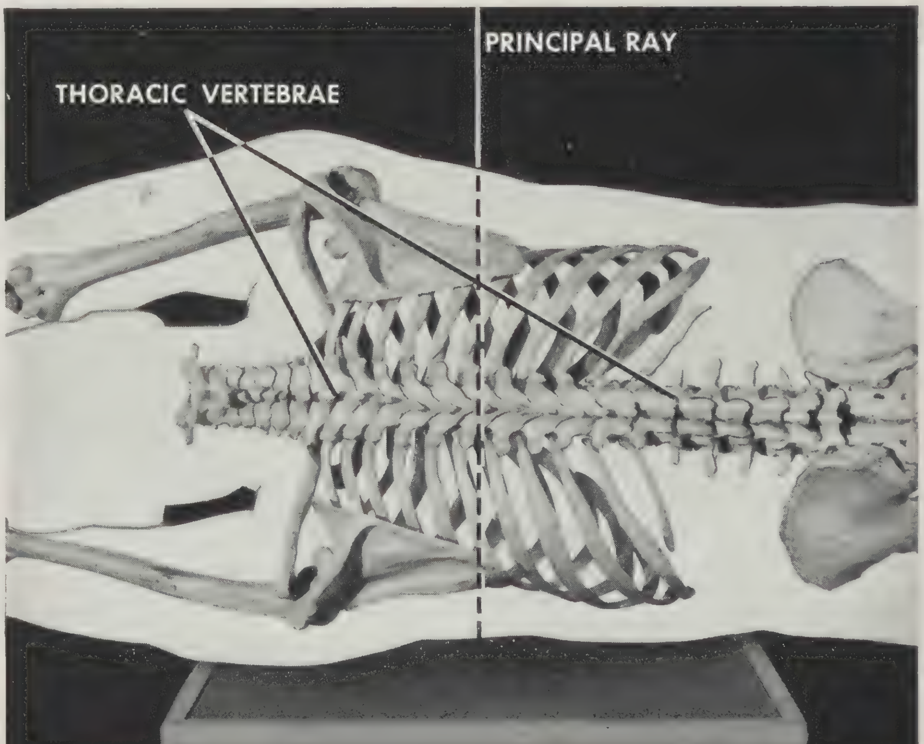


DISTANCE: 30″ — Measure through plane midlevel of sternum

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	64	66	68	70	72	74	76	68	70	72	74	76	78	80	72	74	76	78
MA - SEC					32							65					130		

Fig. 165.—THORACIC SPINE, LATERAL





ANATOMICAL: Thoracic vertebrae and interspaces.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient laterally recumbent, arms extended above head. Plane of acromial processes 7 cm. below upper border of film. Plane of back 8 cm. posterior to midwidth of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Knees flexed, plane of back perpendicular to film. Shallow respiration.

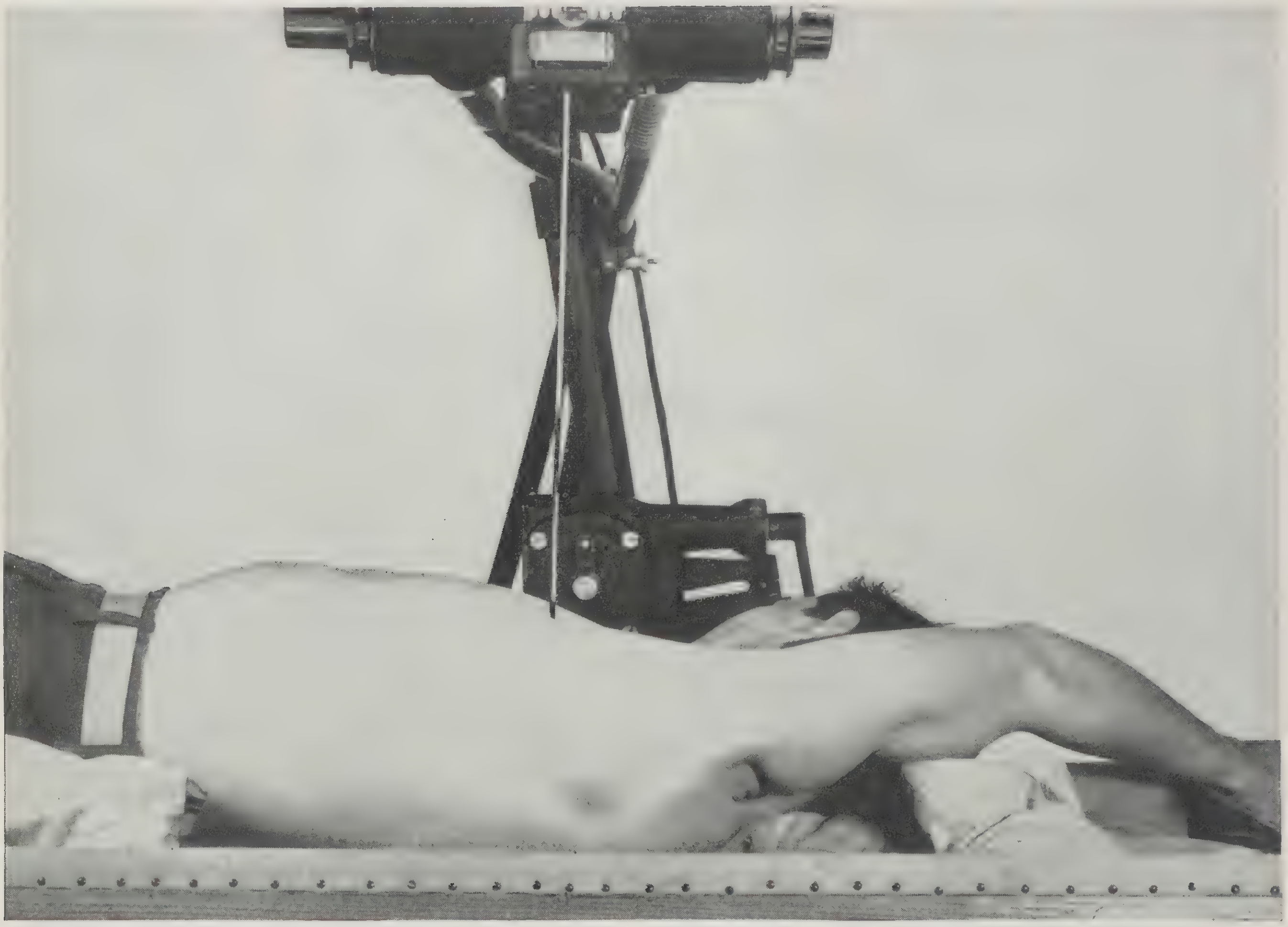
ADDITIONAL: Grid.

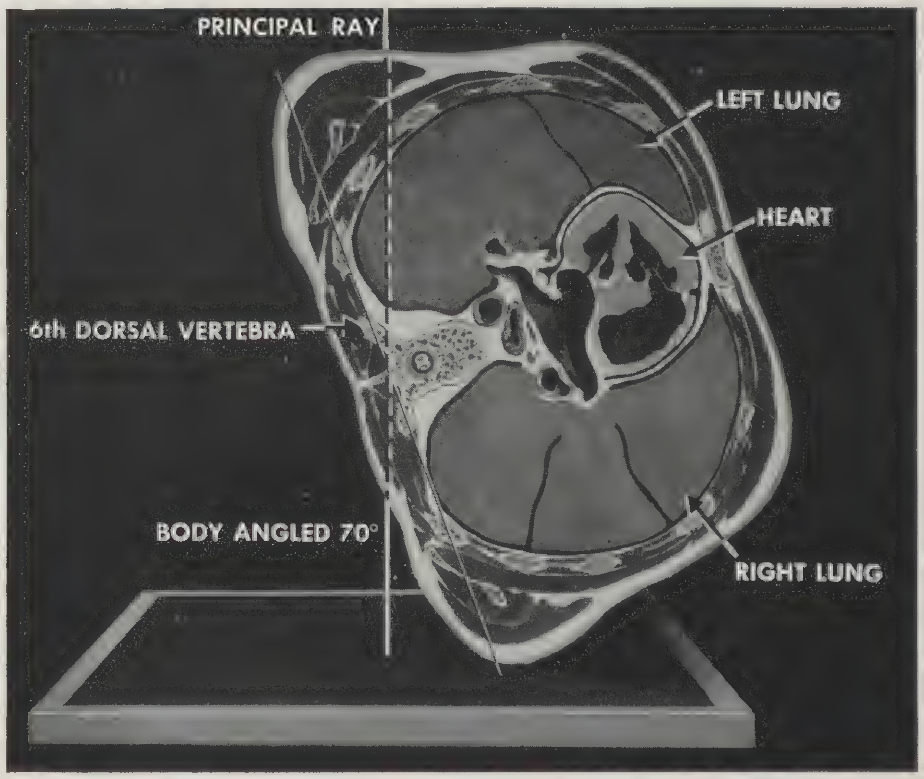
DISTANCE: 30″

Measure through plane, midlevel of sternum, laterally

		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
CMS. THICKNESS		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
VARIABLE KVP	with cardboard holders																		
	with medium screens																		
	with Army wafer grid	62	64	66	68	70	72	74	76	78	70	72	74	76	78	80	82	84	76
MA - SEC						60									120				240

Fig. 166.—THORACIC SPINE, OBLIQUE





ANATOMICAL: Apophyseal joints and articular processes of thoracic vertebrae.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient supine, rotated 70° to side for study. Plane of acromial processes 7 cm. below upper border of film. Spinous processes at midwidth of film.

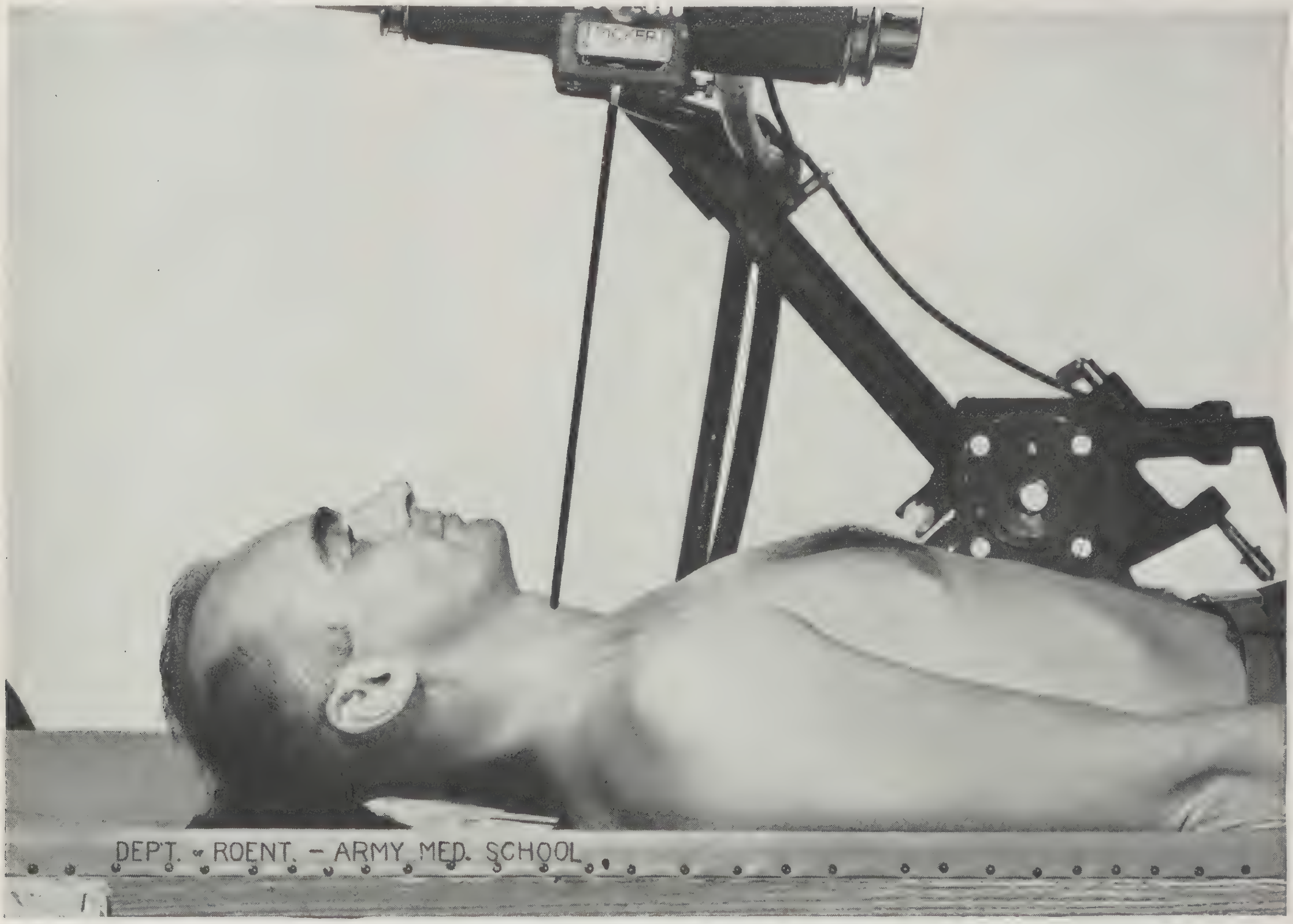
FOCAL SPOT: Align to center of film.

PRECAUTION: Patient in midwidth of film, arms extended, sandbag supporting hip and shoulders, knees forward and slightly flexed.

ADDITIONAL: Grid. Shallow respiration.

DISTANCE: 30″	Measure through path of principal ray at level of midsternum																
CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
VARIABLE KVP	with cardboard holders																	
	with medium screens																	
	with Army wafer grid	70	72	74	76	78	70	72	74	76	78	70	72	74	76	78	80	82
MA - SEC				23					45						90			

Fig. 167.—CERVICAL SPINE, ANTEROPOSTERIOR



ANATOMICAL: Cervical vertebrae and soft tissues.

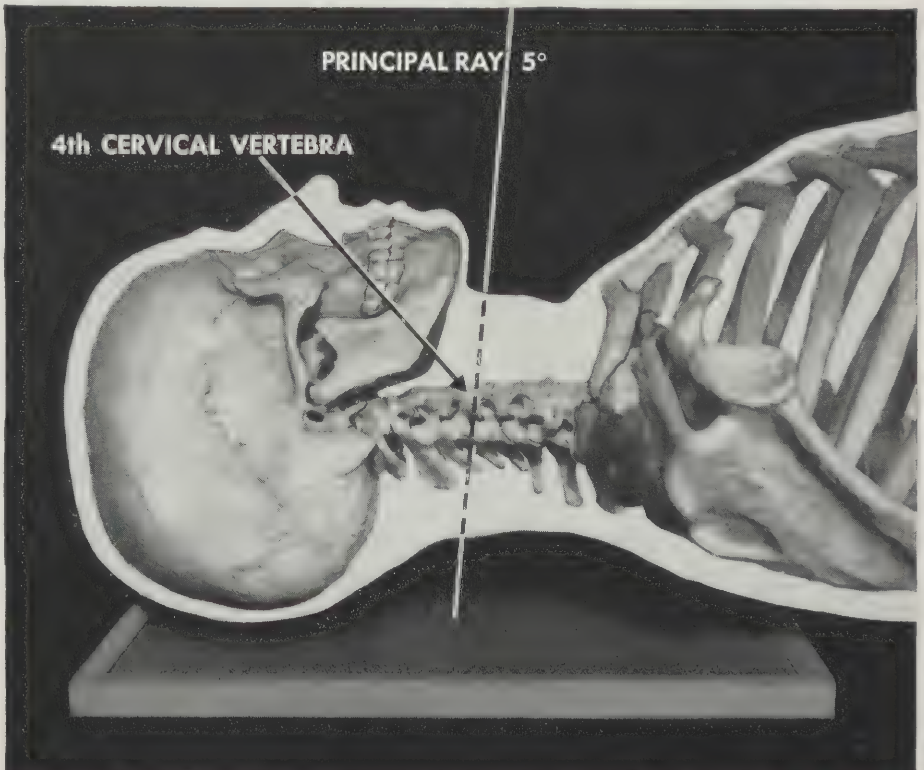
FILM: 10 x 12 inch, lengthwise.

POSITION: Patient supine midsagittal plane of neck in midwidth and perpendicular to film; upper level of thyroid cartilage to midlength of film; head dorsally extended so that plane of lower border of mandible and occiput are perpendicular to film.

FOCAL SPOT: Align to center of film.

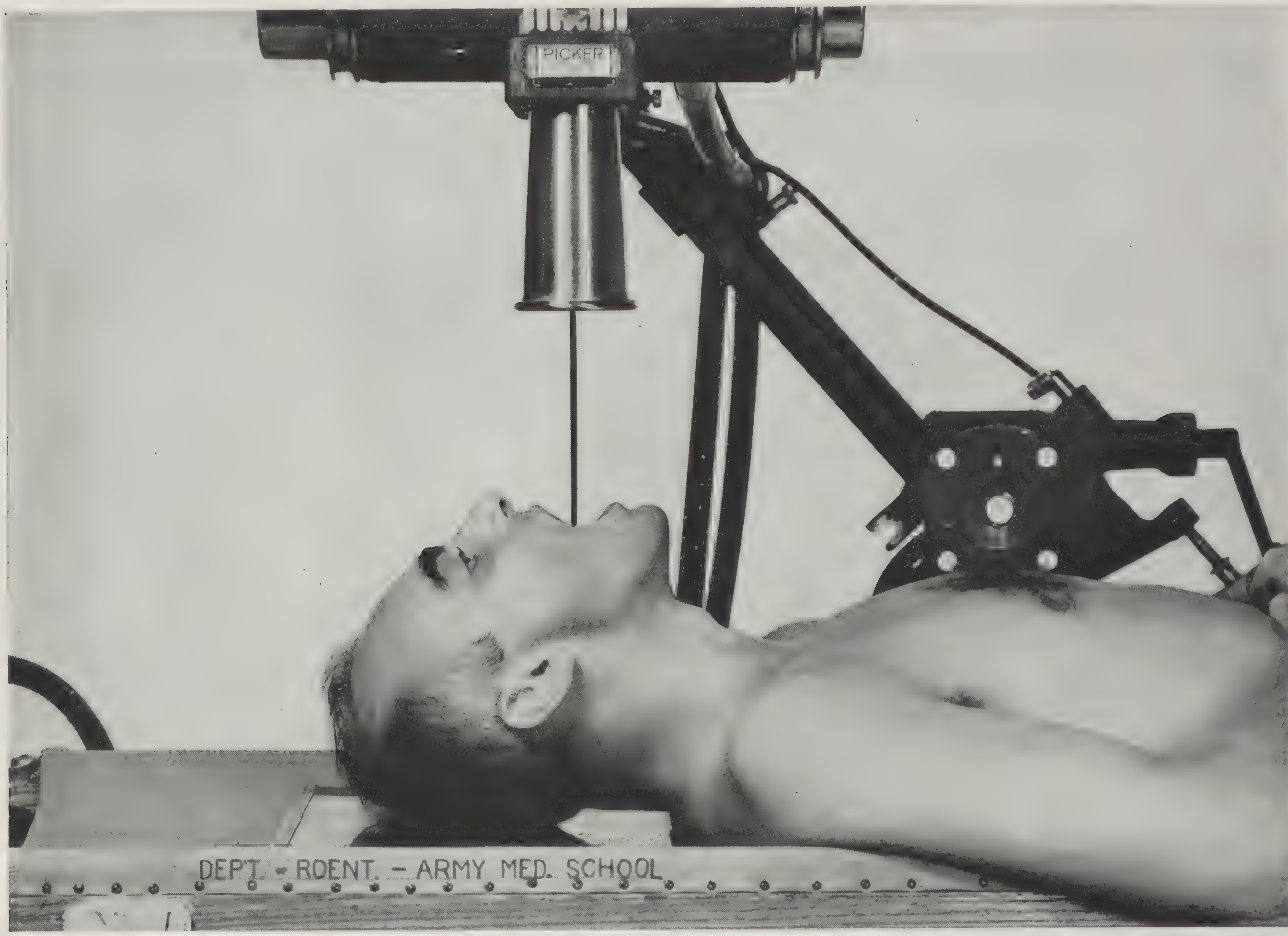
ADDITIONAL: Grid advisable in thick-necked subject.

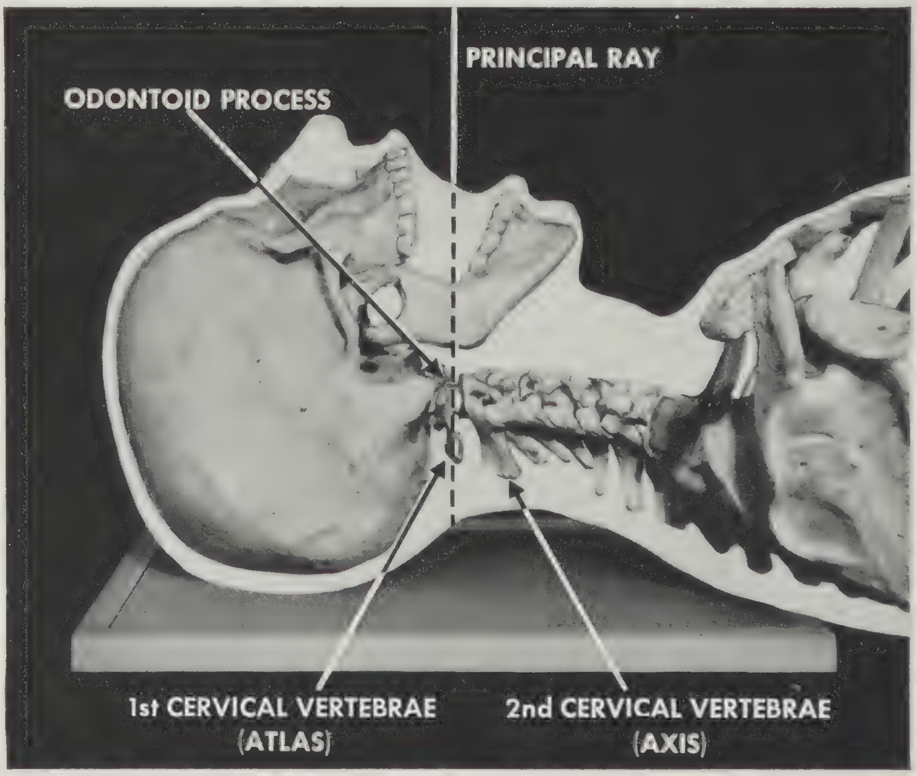
VARIATION: If a long exposure and rapid motion of lower jaw is used, with head immobilized, the shadow of the mandible will not interfere with visualization of the upper vertebrae.



DISTANCE: 30″		Measure through plane upper level thyroid cartilage										
CMS. THICKNESS		7	8	9	10	11	12	13	14	15	16	17
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.
	with medium screens.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	68	70	72	74	76	78	80	72	74	76	78
MA - SEC					20					40		

Fig. 168.—CERVICAL SPINE, (odontoid) ANTEROPOSTERIOR





ANATOMICAL: 1st and 2nd cervical vertebrae.

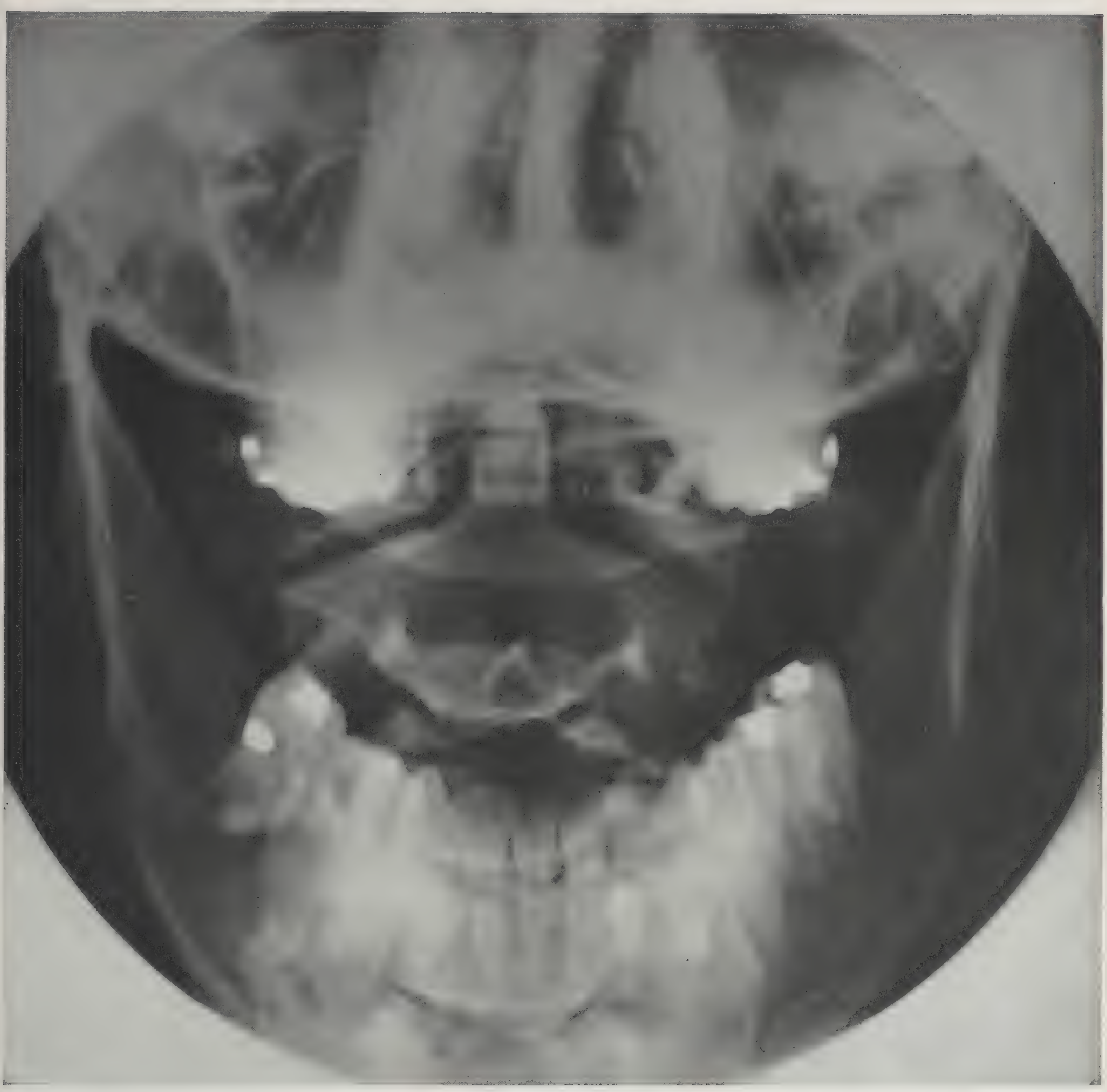
FILM: 8 x 10 inch, lengthwise.

POSITION: Patient supine; plane through tips of mastoid processes to midlength of film.

FOCAL SPOT: Align to point midwidth and 2 cm. below hard palate to center of film.

PRECAUTION: Plane of hard palate perpendicular to film. Head slightly extended. Sterilized cork or other non-opaque material may be used to keep mouth open.

ADDITIONAL: Grid advisable.

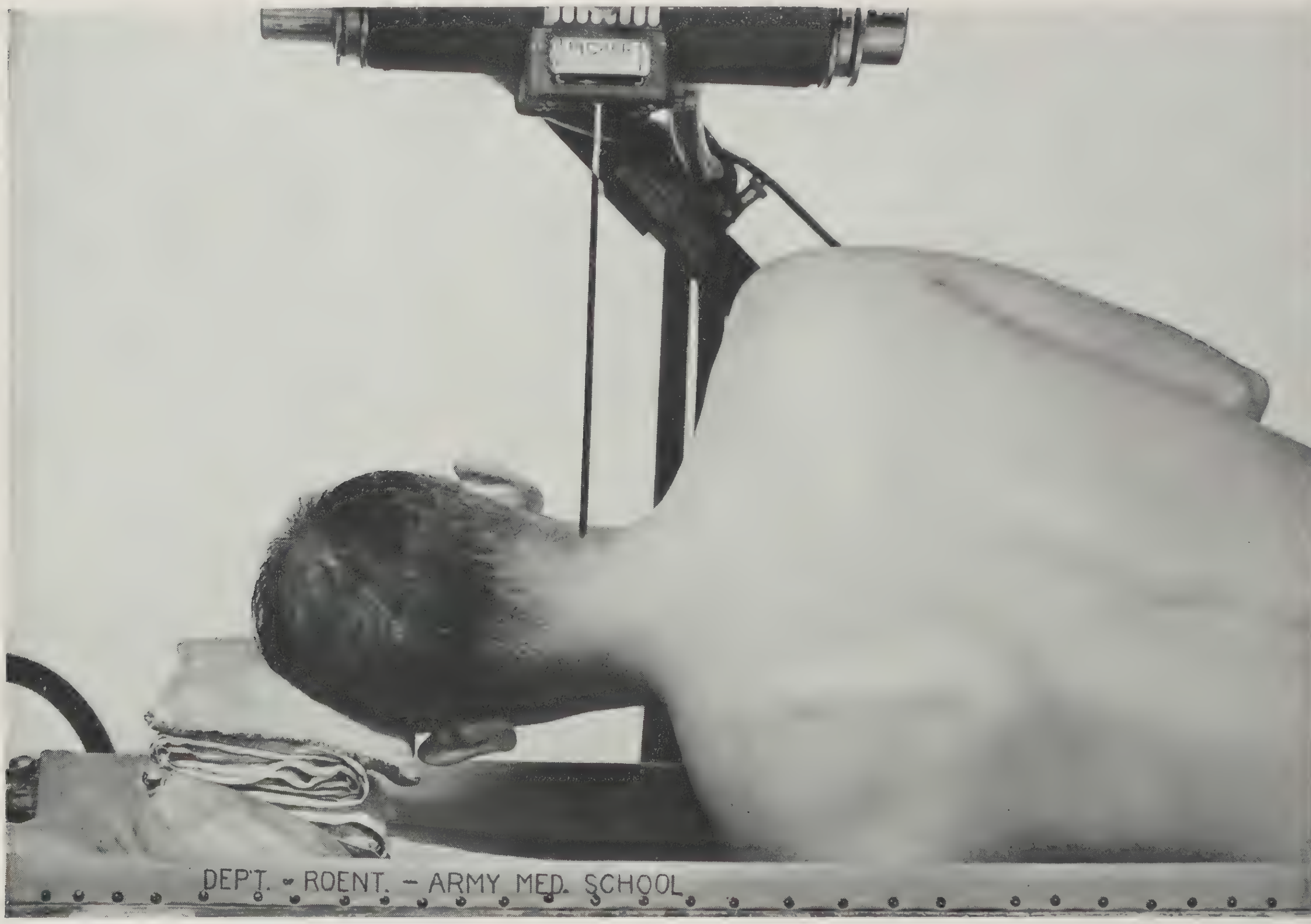


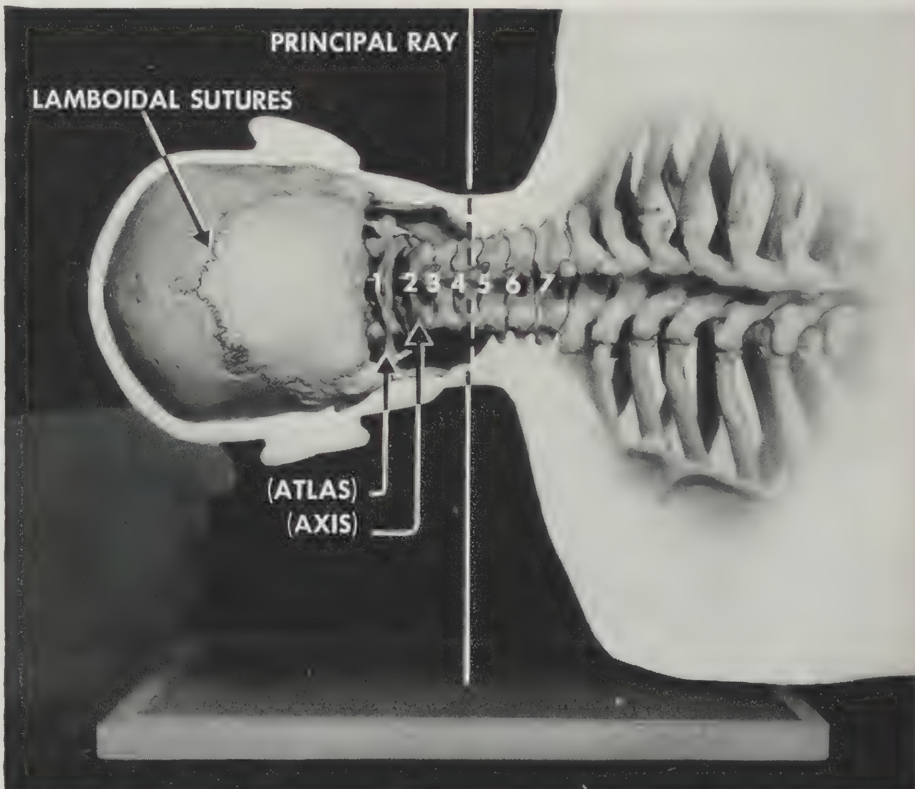
DISTANCE: 30″ Measure through plane of principal ray—angle of open mouth to base of occiput

CMS. THICKNESS		12	13	14	15	16	17	18	19	20	21	22	23
VARIABLE KVP	with cardboard holders												
	with medium screens	62	64										
	with Army wafer grid			66	68	70	72	74	76	78	80	82	84
MA - SEC		20		40									

AUXILIARIES: CONE.

Fig. 169.—CERVICAL SPINE, LATERAL (recumbent)





ANATOMICAL: Vertebral bodies, spinous processes, intervertebral spaces, paraspinal soft tissues.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient laterally recumbent, head supported, level of auditory meati to upper border of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Cervical spine parallel to film; chin slightly extended to avoid superimposition of mandible over upper vertebrae; maximum depression of shoulders.

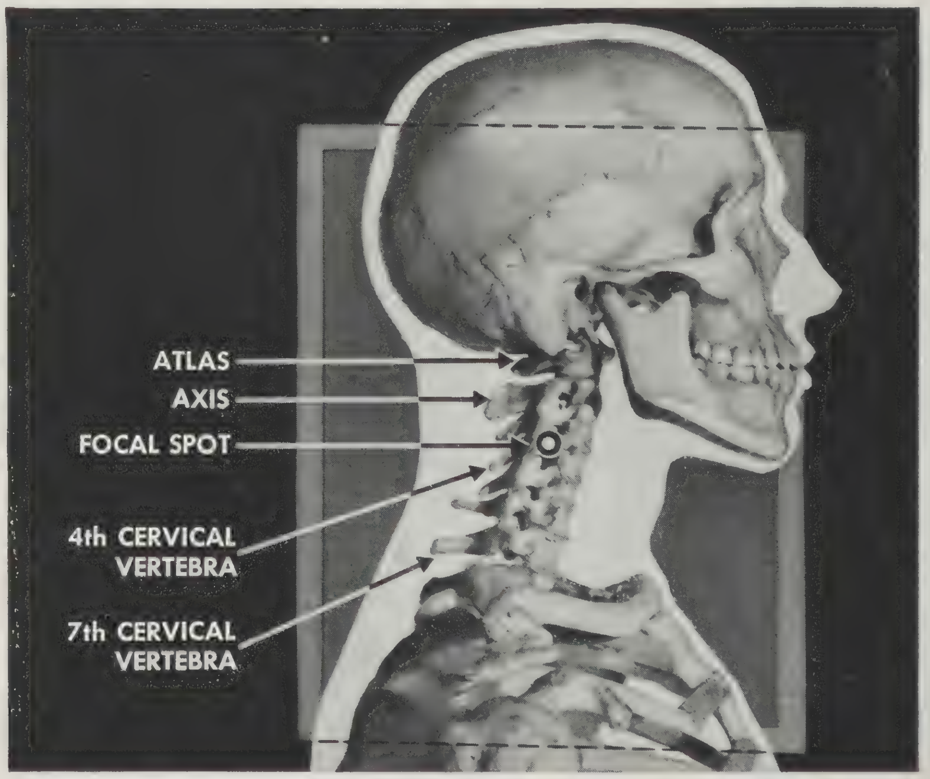
ADDITIONAL: Grid advisable.

DISTANCE: 30″ Measure through plane of principal ray through middle of neck

		7	8	9	10	11	12	13	14	15	16	17
CMS. THICKNESS		7	8	9	10	11	12	13	14	15	16	17
VARIABLE KVP	with cardboard holders											
	with medium screens											
	with Army wafer grid	70	72	74	76	68	70	72	74	76	78	80
MA - SEC			12						24			

AUXILIARIES: CONE.

Fig. 170.—CERVICAL SPINE, LATERAL (erect)



ANATOMICAL: As for previous positions.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient sitting, supporting film at side of shoulder (if supports are not available) cassette parallel to sagittal plane of patient.

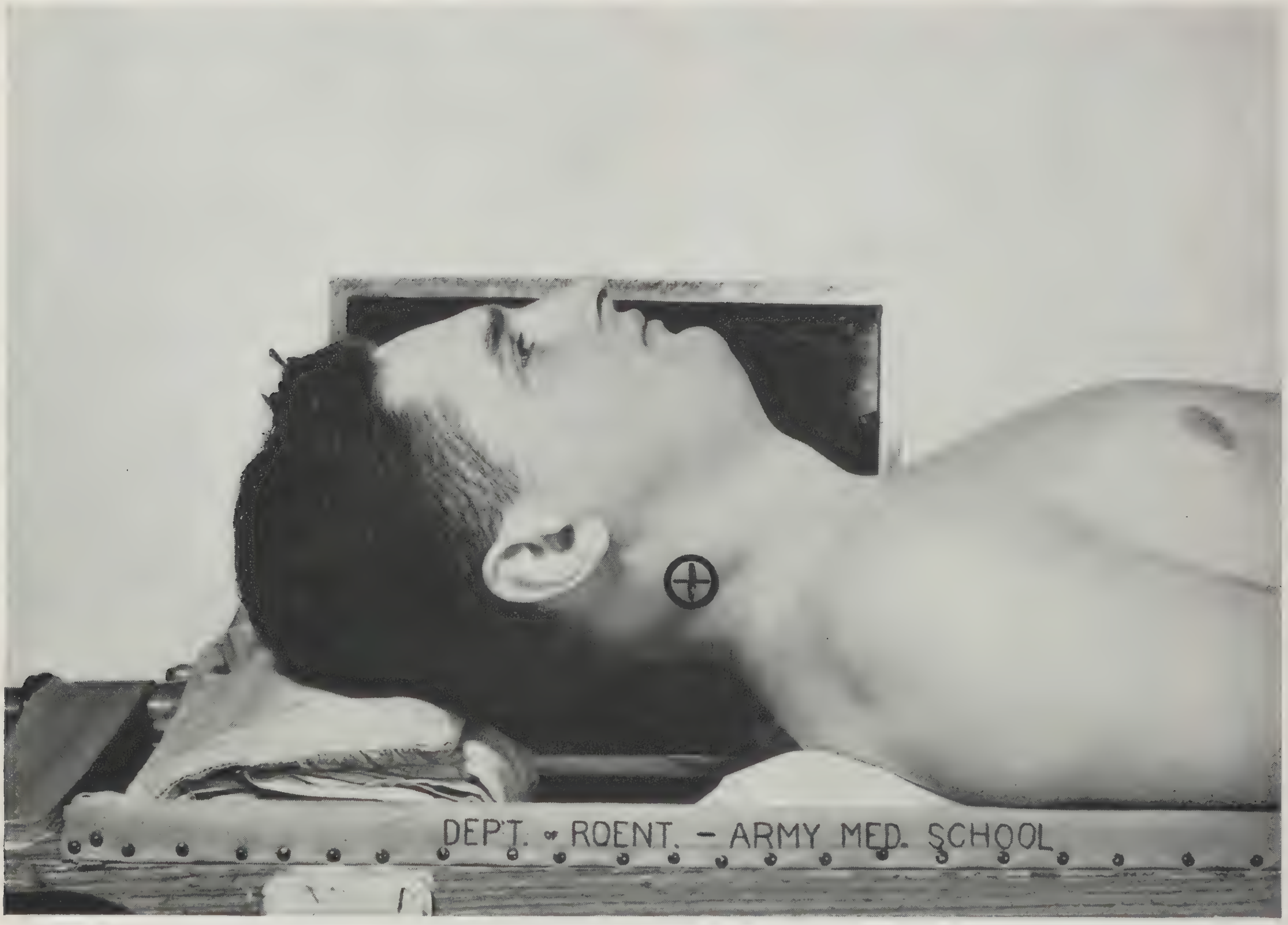
FOCAL SPOT: Align to center of film.

PRECAUTION: Head erect, midsagittal plane vertical. Chin slightly extended, shoulders depressed.

ADDITIONAL: Respiration suspended.

DISTANCE: 72″	Measure through plane of principal ray through middle of neck											
CMS. THICKNESS		7	8	9	10	11	12	13	14	15	16	17
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	70	72	74	76	68	70	72	74	76	78	80
MA-SEC			15						30			

Fig. 171.—CERVICAL SPINE, LATERAL (stretcher patient)



ANATOMICAL: As for preceding positions.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient supine, head may be supported on sandbag.

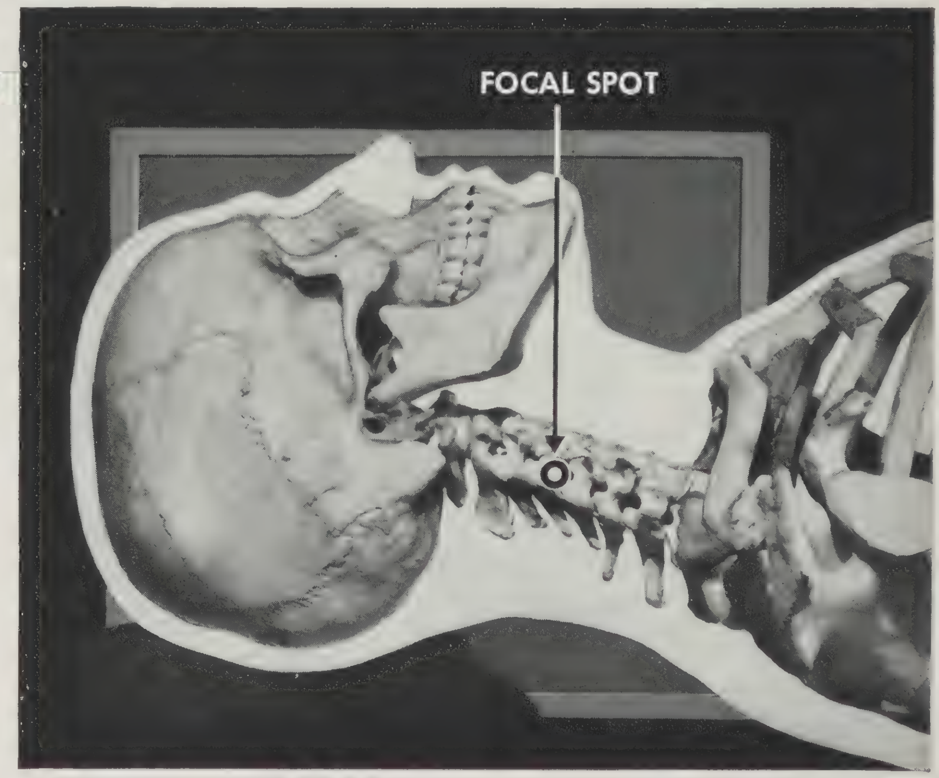
ONLY IF CONDITION OF PATIENT MAKES PROCEDURE SAFE. Film vertical, lower border of cassette resting against shoulder.

FOCAL SPOT: Align to center of film.

PRECAUTION: Do not move patient's head in cases of suspected cervical fracture without competent advice.

ADDITIONAL: Grid advisable.

NOTE: By placing cassette along shoulder in plane parallel to midsagittal plane all cervical vertebrae may be included on roentgenogram.

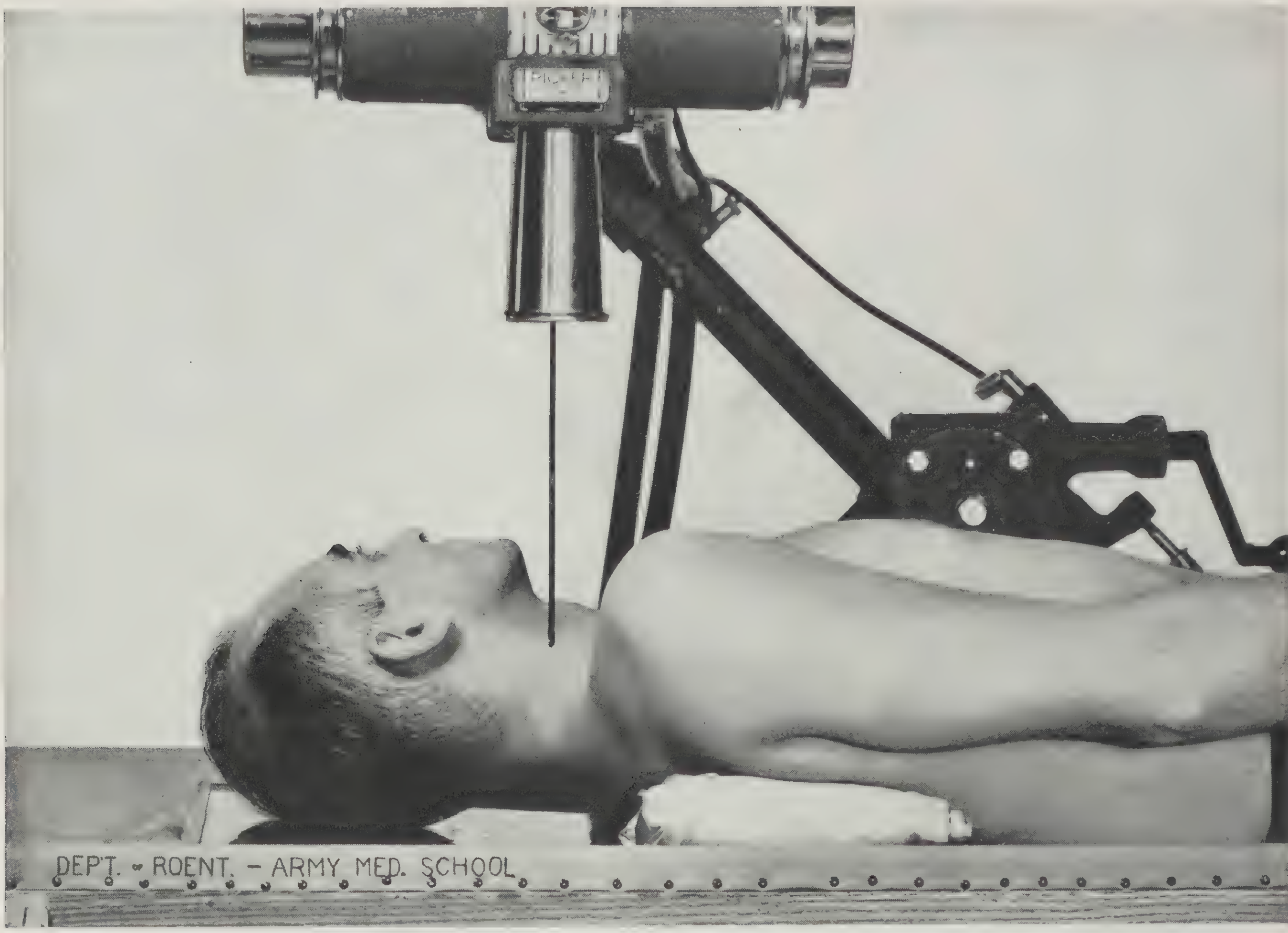


DISTANCE: 30″ Measure through plane upper border of thyroid cartilage

<table>
<tr><th colspan="2">CMS. THICKNESS</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th>16</th><th>17</th></tr>
<tr><td rowspan="3">VARIABLE KVP</td><td>with cardboard holders</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>with medium screens</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>with Army wafer grid</td><td>70</td><td>72</td><td>74</td><td>76</td><td>68</td><td>70</td><td>72</td><td>74</td><td>76</td><td>78</td><td>80</td></tr>
<tr><td colspan="2">MA - SEC</td><td colspan="4">12</td><td colspan="7">24</td></tr>
</table>

AUXILIARIES: CONE.

Fig. 172.—CERVICAL SPINE, OBLIQUE



ANATOMICAL: Intervertebral foramina; pedicles.

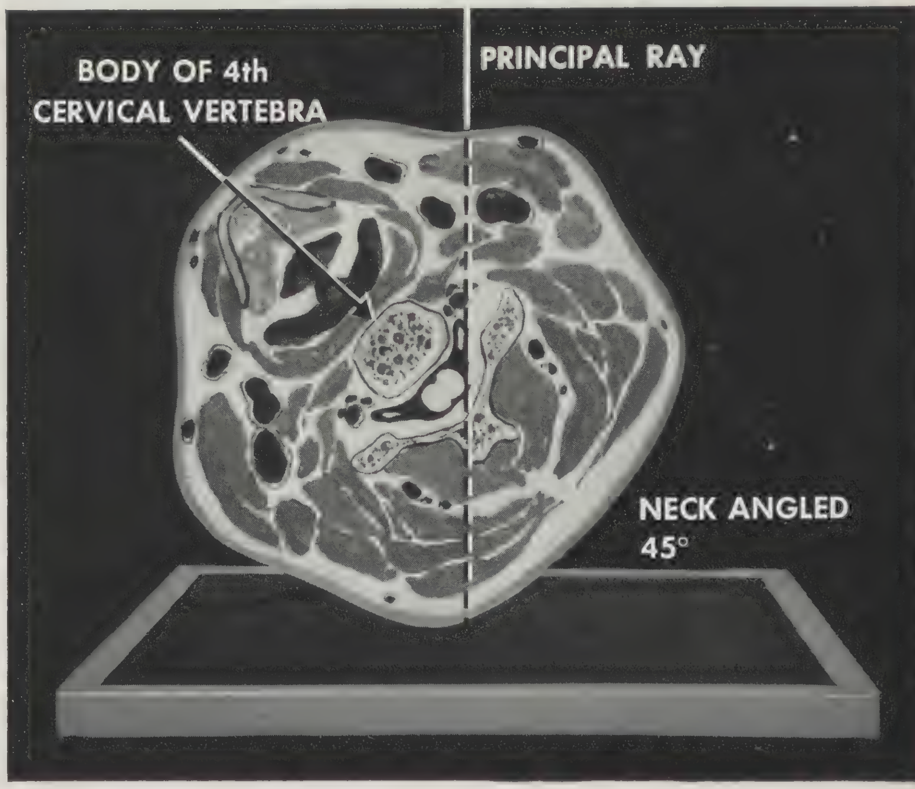
FILM: 10 x 12 inch, lengthwise.

POSITION: Patient supine, level, upper border of thyroid cartilage to midlength of film; head and upper neck rotated (so side under study) 45° and thorax about 10–20°.

FOCAL SPOT: Align to level upper border of thyroid cartilage and midwidth of neck.

PRECAUTION: Sandbags used to elevate shoulder.

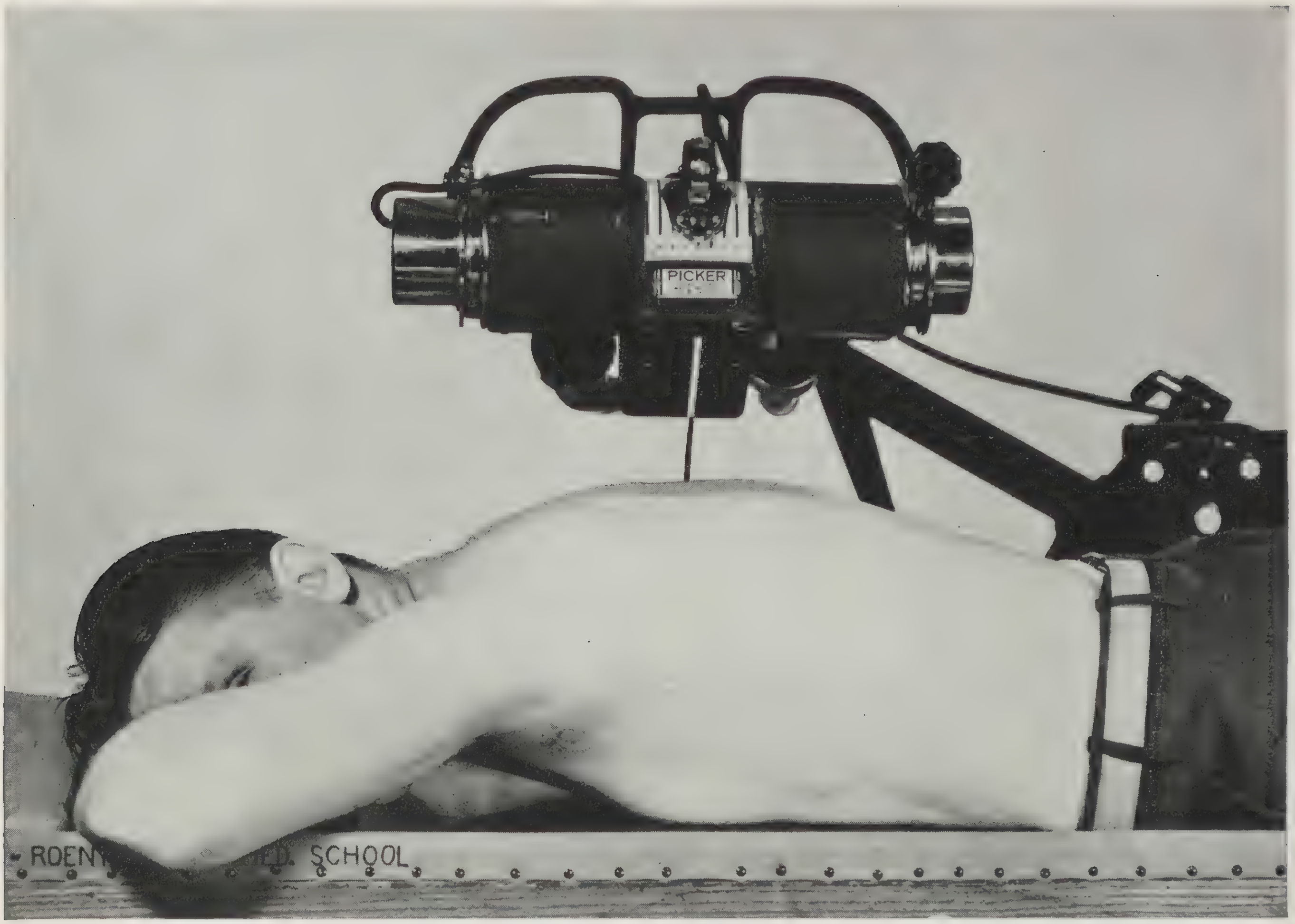
ADDITIONAL: Grid.

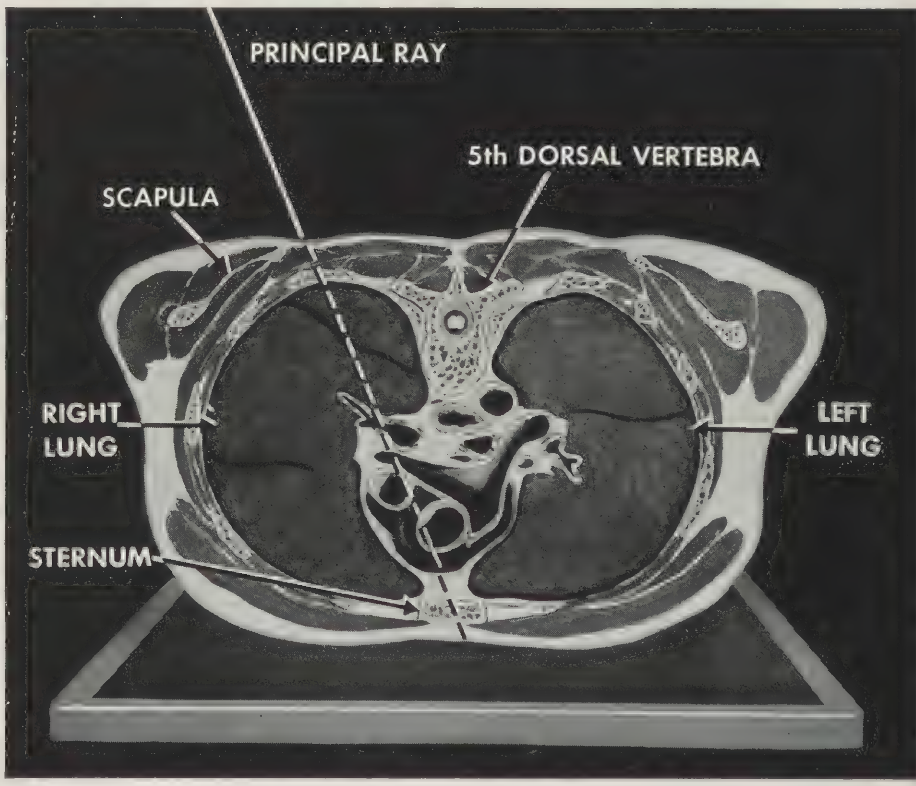


DISTANCE: 30″	Measure through plane, upper border thyroid cartilage, obliquely										
CMS. THICKNESS		7	8	9	10	11	12	13	14	15	16
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	70	72	74	76	78	70	72	74	76	78
MA - SEC.				12					24		

AUXILIARIES: CONE.

Fig. 173.—STERNUM, POSTERO-ANTERIOR OBLIQUE





ANATOMICAL: Sternum, sterno-clavicular joints; costo-sternal articulations; ends of clavicles.

FILM: 10 x 12 inch, lengthwise.

POSITION: Prone, arms at sides. Sternum at midwidth of film. Upper border of manubrium 4 cm. below upper border of cassette.

FOCAL SPOT: Displace tube 8 to 10 cm. to the right of the midline, and angle tube sufficiently to have principal ray strike 8 cm. lateral to spine and emerge through sternum.

PRECAUTION: Suspended respiration or shallow respiration.

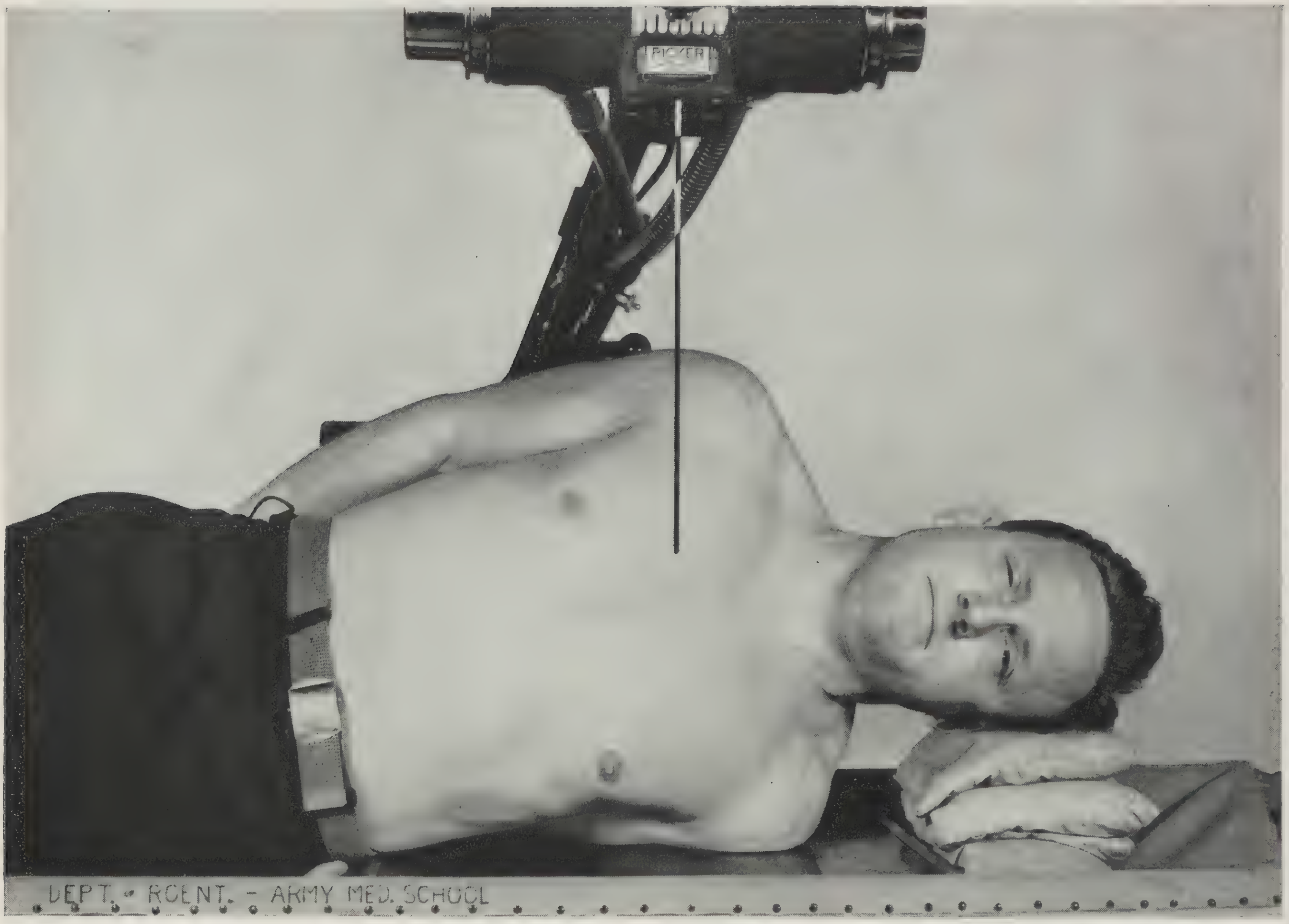
VARIATION: Similar results may be obtained by rotating patient 20 to 30°, left side anterior; focal spot aligned as above; principal ray directed vertically, lateral to the spine on the side elevated.

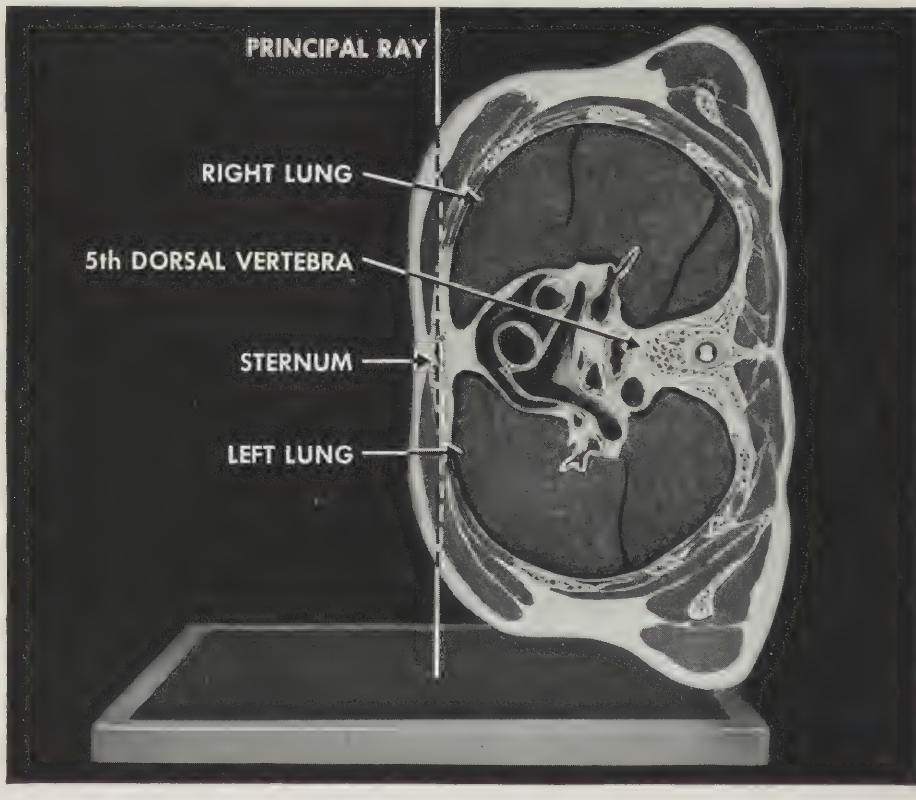
DISTANCE: 30″ — Measure plane through midlength of sternum

CMS. THICKNESS		17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	62	64	66	68	70	72	74	76	78	70	72	74	76	78
MA - SEC						40							80		

AUXILIARIES: CONE.

Fig. 174.—STERNUM, LATERAL





ANATOMICAL: Manubrium, body and xiphoid of sternum; regional soft tissues.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient laterally recumbent, midsagittal plane parallel to film. Manubrium 3 cm. below upper border of cassette, sternum at midwidth of film.

FOCAL SPOT: Align to point 3 cm. below the sternal angle.

PRECAUTION: Arms thrown back. Suspend respiration. Head supported on sandbags.

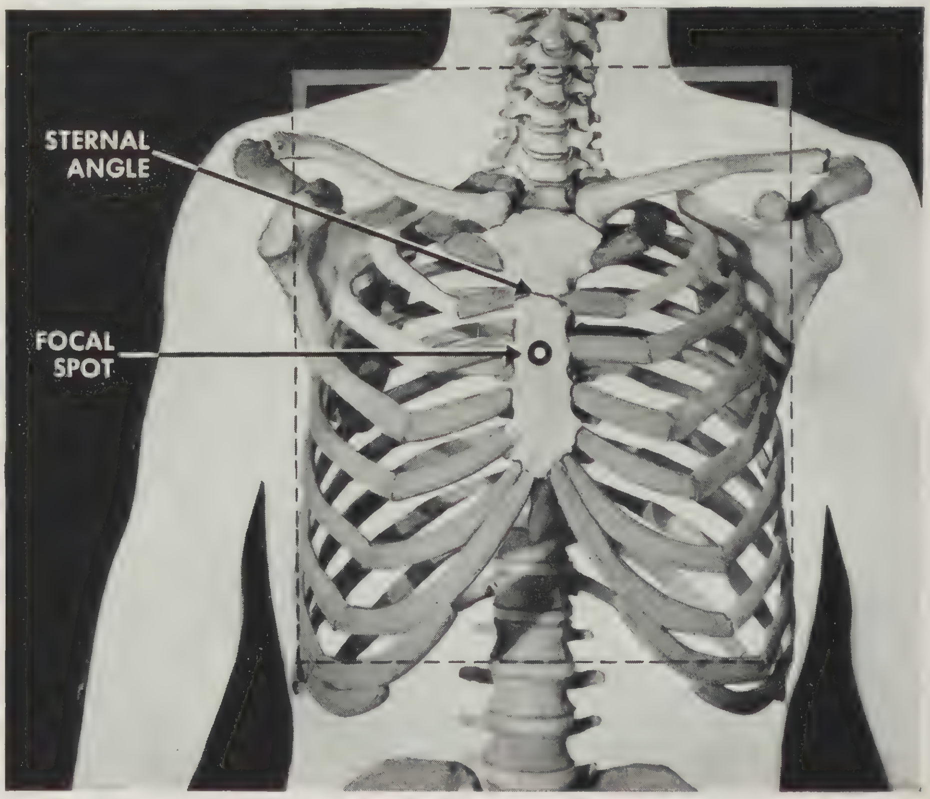
ADDITIONAL: Immobilization by sandbag against back. Grid.

DISTANCE: 30″

Measure plane through midlength of sternum, laterally

CMS. THICKNESS	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
VARIABLE KVP with cardboard holders																				
VARIABLE KVP with medium screens	58	60	62	64	66	68	70	72	74	76	78	70	72	74	76	78	70	72	74	76
VARIABLE KVP with Army wafer grid																				
MA-SEC						10								20				40		

Fig. 175.—RIBS, UPPER, A.P., P.A., OR OBLIQUE



ANATOMICAL: Ribs above the diaphragm; regional soft tissues.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient supine, prone or oblique; site of suspected injury to center of film.

FOCAL SPOT: Align to center of film.

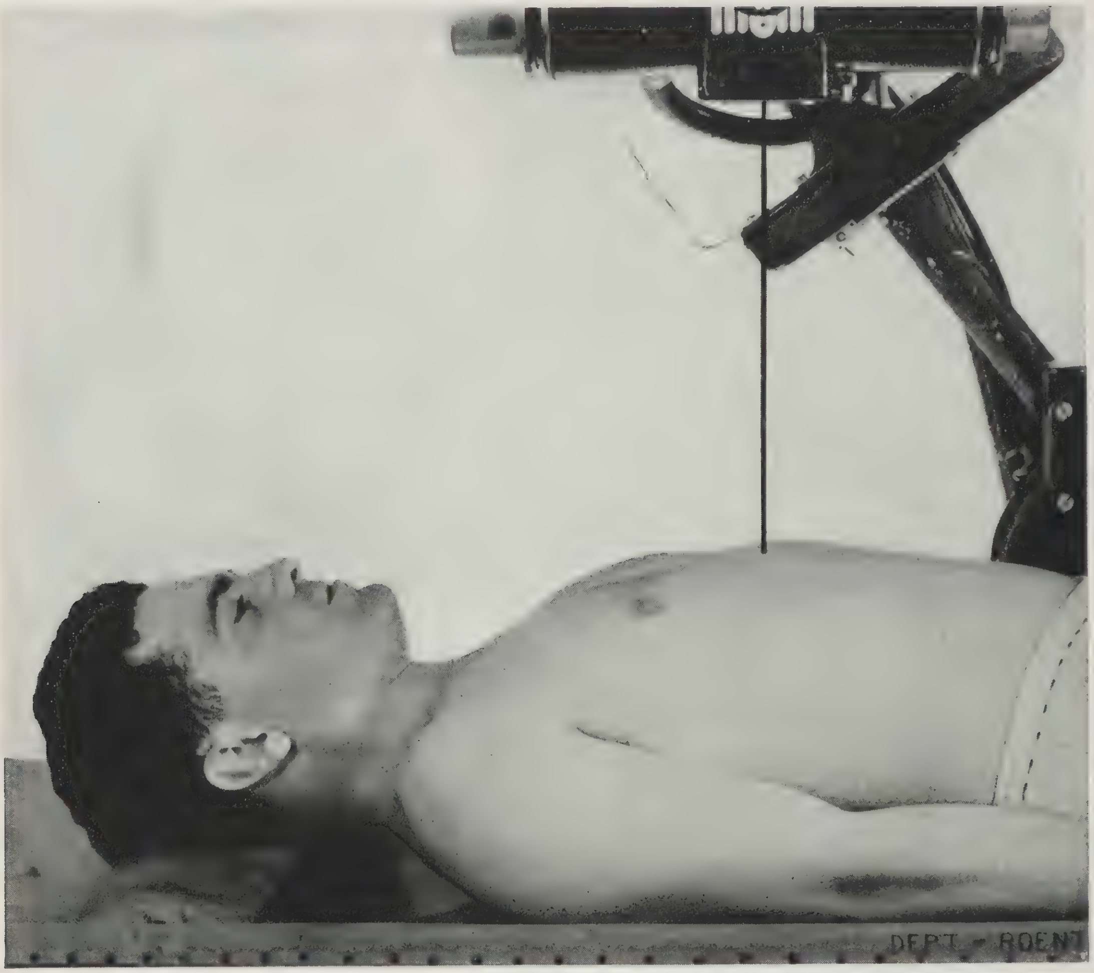
PRECAUTION: Respiration suspended in maximum inspiration.

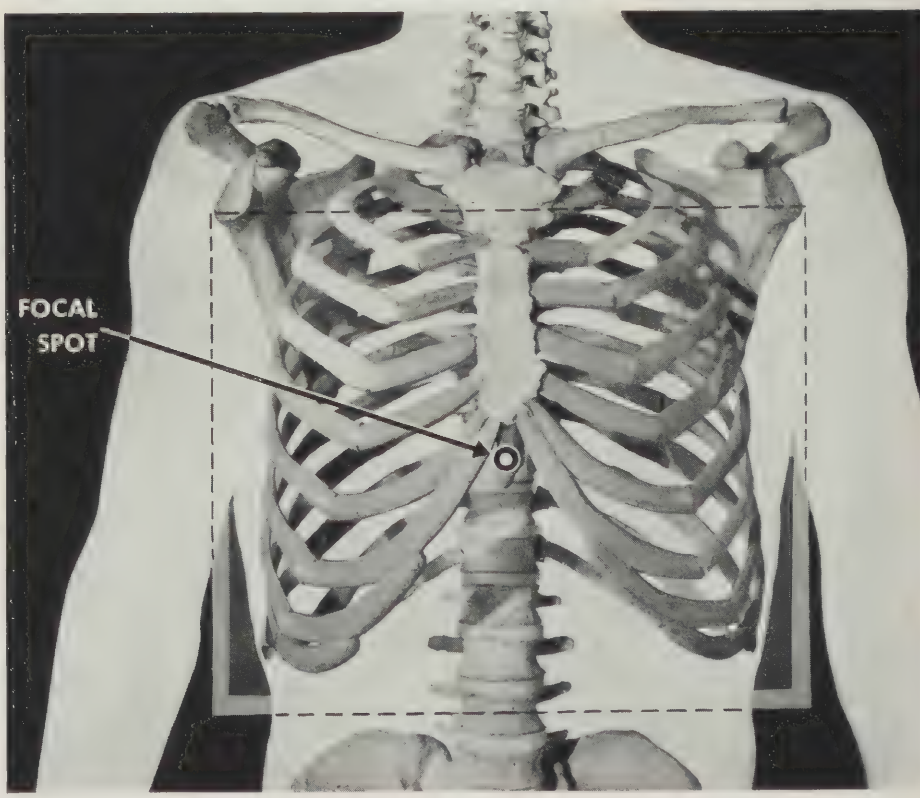
NOTE: Grid used for patients over 23 cm. and for ribs below diaphragm. If fracture is posterior, an anteroposterior projection is preferred. Anterior fractures are visualized best by posteroanterior projections; axillary portions, in right or left obliques.

DISTANCE: 30″		Measure through plane of principal ray														
CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	54	56	58	60	62	64	56	58	60	62	64	66	68	70	72
MA - SEC.	with wafer grid			15								30				
MA - SEC.	without grid			6								12				

On oblique positions, use above kvp, double Ma-sec.

Fig. 176.—RIBS, LOWER, ANTEROPOSTERIOR





ANATOMICAL: Ribs below the diaphragm; diaphragm, spleen, liver, both kidneys, psoas margins, etc.

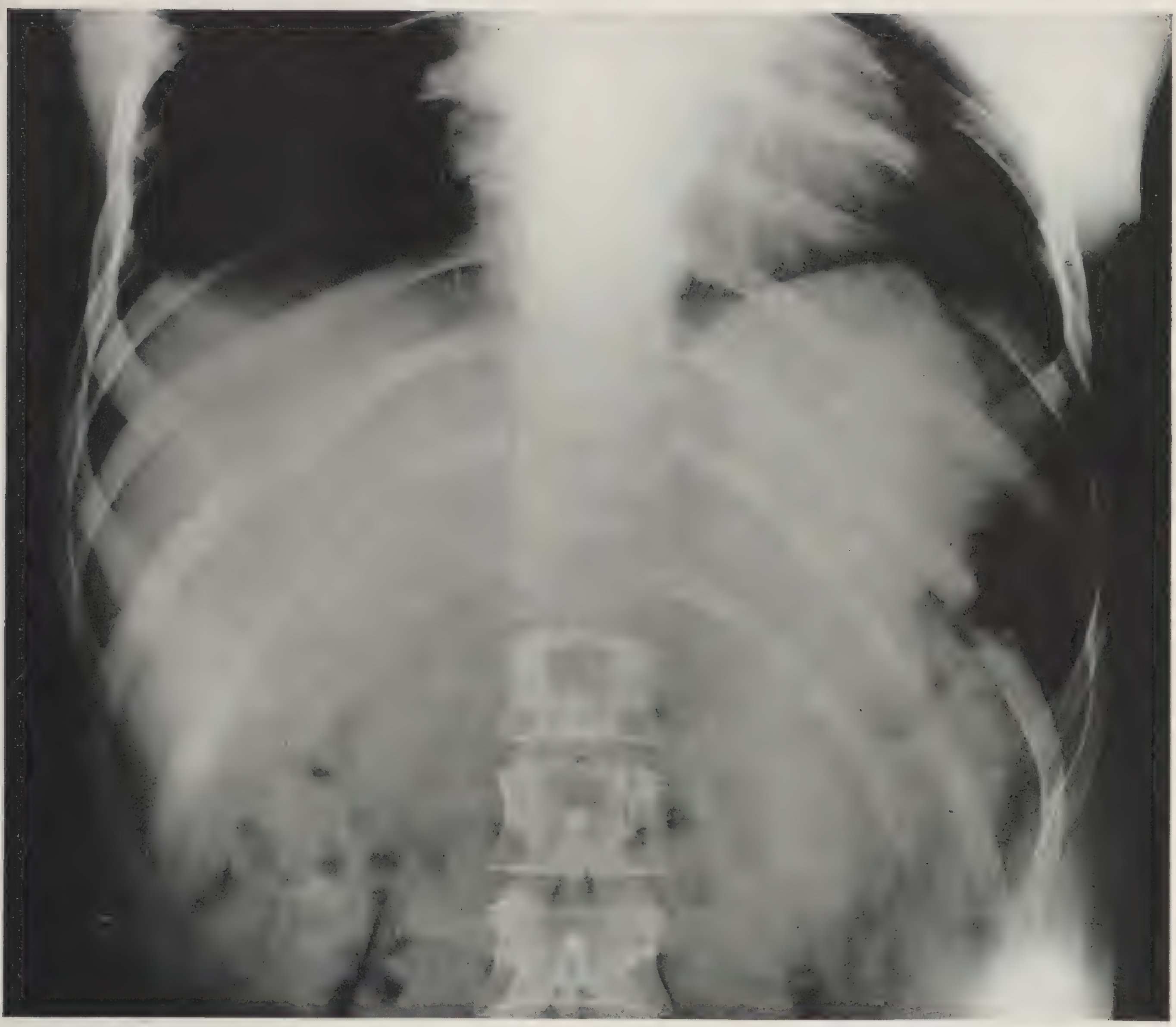
FILM: 14 x 17 inch, widthwise.

POSITION: Patient supine, level of iliac crests to lower border of cassette.

FOCAL SPOT: Align to center of film.

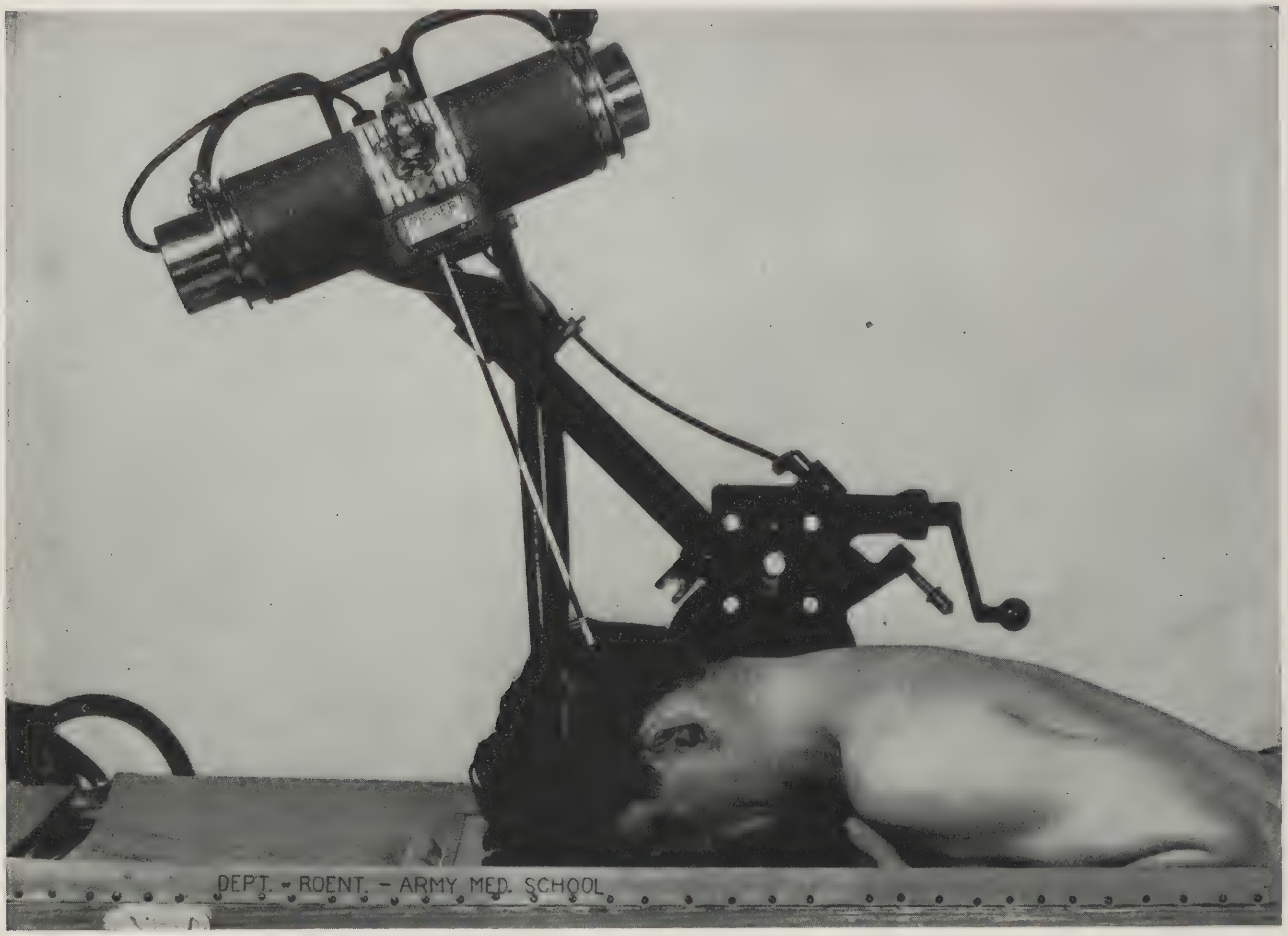
PRECAUTION: Respiration suspended.

NOTE: Grid advisable; immobilization band may be placed over lower portion of thorax. This projection is used for visualization of adrenal.



DISTANCE: 30″	Measure through plane midway between xiphoid and umbilicus													
CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27	28
VARIABLE KVP	with cardboard holders													
	with medium screens													
	with Army wafer grid	56	58	60	62	64	66	68	70	72	74	76	78	80
MA - SEC								50						

Fig. 177.—SKULL, POSTERO-ANTERIOR



ANATOMICAL: Frontal bone, orbits, frontal sinus and ethmoidal cells. Secondarily, petrous ridges.

FILM: 8 x 10 inch, lengthwise.

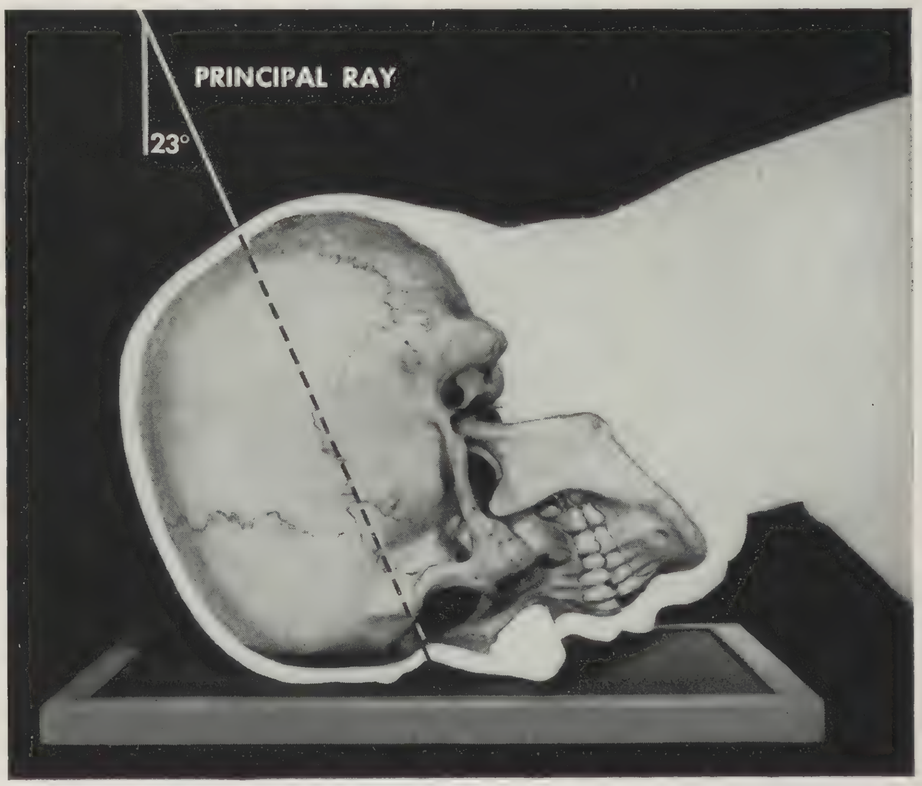
POSITION: Patient prone, forearms flexed beneath chest, nose and forehead in contact with film; nasion in center; plane through external auditory meati and external canthi perpendicular to film.

FOCAL SPOT: Align to point 6 to 7 cm. above external occipital protuberance with principal ray angled 23° caudally, emerging through nasion to center of film.

PRECAUTION: Midsagittal plane perpendicular to film. Suspended respiration.

ADDITIONAL: Immobilization grid.

VARIATIONS: Petrous ridges may be seen clearly through orbits by shifting out caudally and angling 10 to 15° cephalad.



DISTANCE: 30″ — Measure through plane of principal ray projecting at nasion

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	64	66	68	70	72	74	76	78	80	72	74	76	78
MA - SEC		64									128			

AUXILIARIES: CONE for 10 x 12″ coverage.

Fig. 178.—SKULL, LATERAL

ANATOMICAL: Frontal, parietal, temporal, and occipital bones, sella turcica; secondarily, paranasal sinuses, facial bones.

FILM: 10 x 12 inch, widthwise.

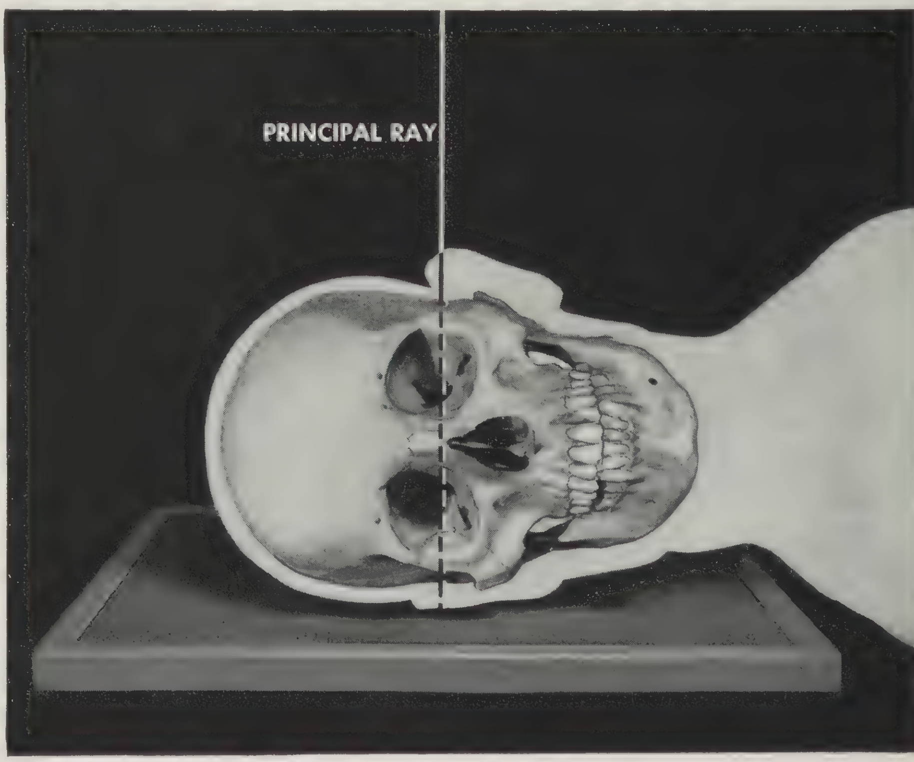
POSITION: Patient prone; forearm flexed beneath chest; vertex 5 cm. below upper border of film. Midsagittal plane parallel to film. (Viewed from end and side of table.)

FOCAL SPOT: Principal ray to center of film. Align to point 3 cm. anterior and 2 cm. above external auditory meatus.

PRECAUTION: Head extended, interpupillary line perpendicular to film. Chin supported (fist or cork). Respiration suspended.

ADDITIONAL: Grid advisable. Fixation band if available.

NOTE: For stereoscopic films ordinarily shift tube in caudad-cephalad direction.

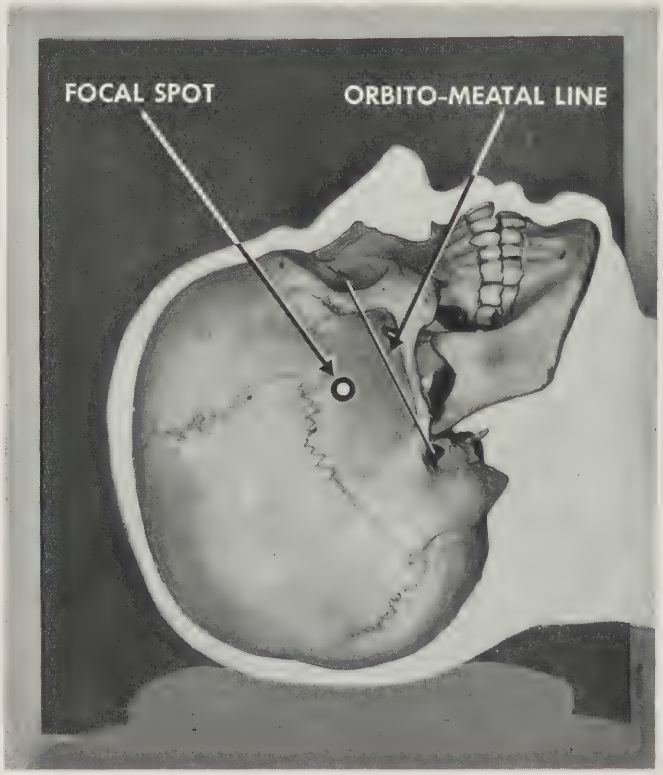


DISTANCE: 30″	Measure through plane of external auditory meati									
CMS. THICKNESS	12	13	14	15	16	17	18	19	20	21
VARIABLE KVP — with cardboard holders	.	.	.	.	.	.	.	.	.	.
VARIABLE KVP — with medium screens	66	68								
VARIABLE KVP — with Army wafer grid	.	.	70	72	74	76	78	80	82	84
MA - SEC	$\underbrace{\quad 12 \quad}$		$\underbrace{\quad 24 \quad}$							

AUXILIARIES: CONE for 10 x 12″ coverage.

Fig. 179.—SKULL, LATERAL (stretcher)

ANATOMICAL: As for standard lateral skull position.
FILM: 10 x 12 inch, vertical and widthwise.
POSITION: Patient supine, head slightly elevated on non-opaque support; midsagittal plane parallel to film.
FOCAL SPOT: Align to point 3 cm. anterior and 2 cm. above external auditory meati to center of film.
PRECAUTION: Interpupillary line perpendicular to cassette. Vertex 5 cm. below upper border of cassette. Film held in position by sandbags.
NOTE: This position of particular value in severely injured or unconscious patients. Place film in contact with side suspected of injury. NEVER MANIPULATE HEAD OF PATIENT SUSPECTED OF FRACTURE OF CERVICAL VERTEBRAE. Grid advisable.

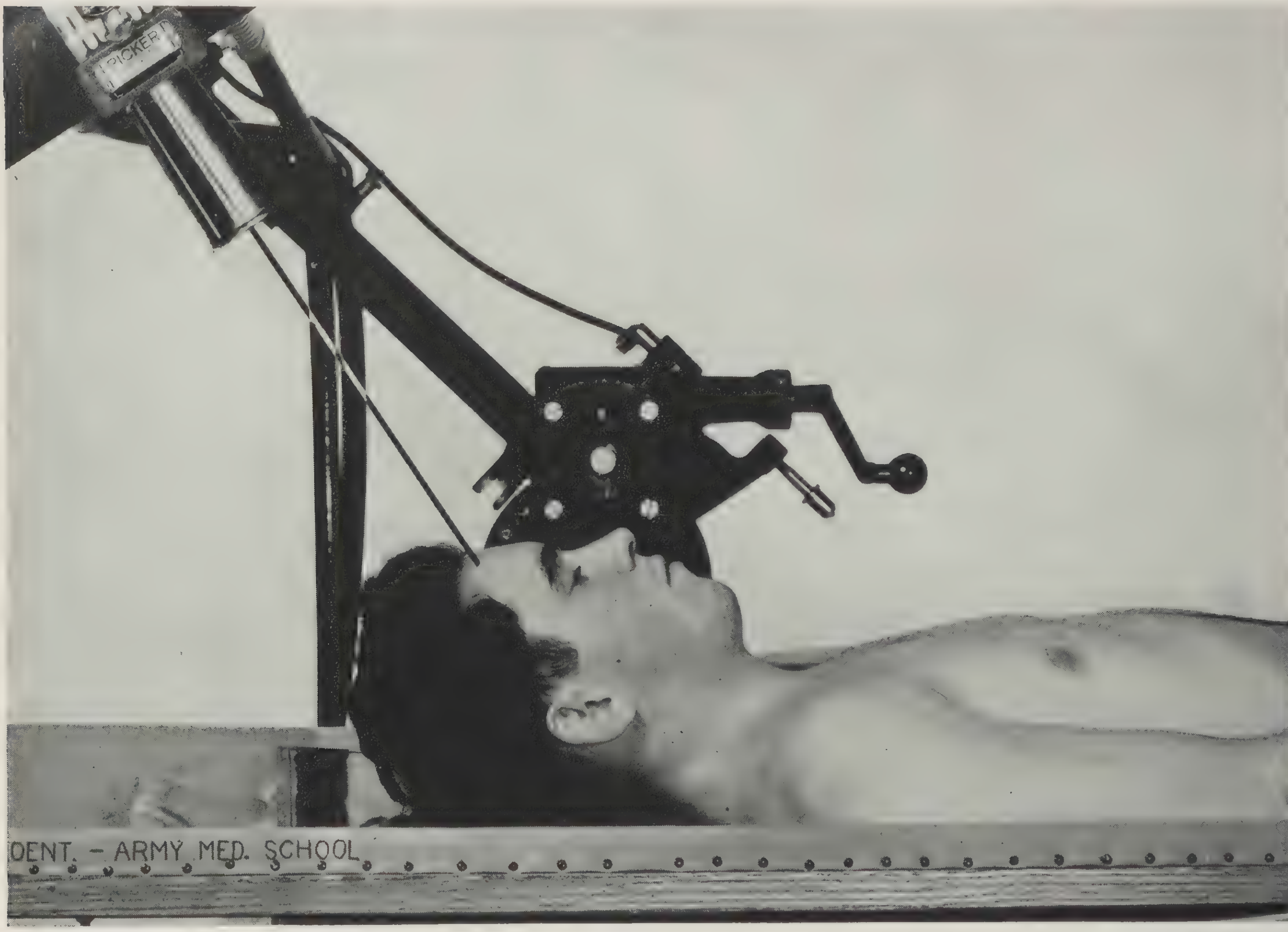


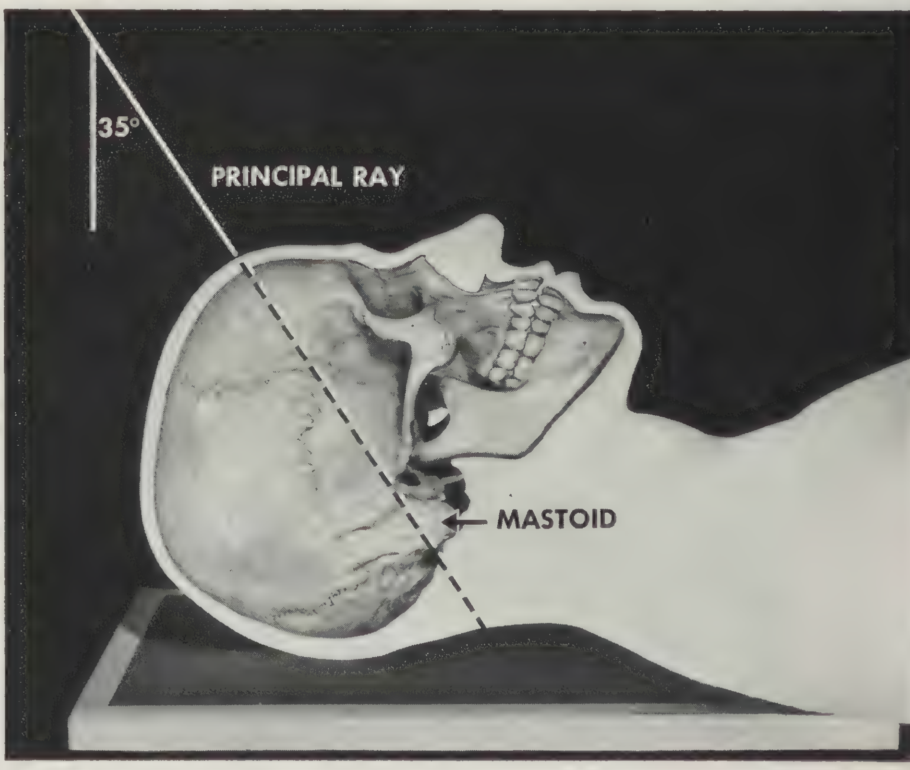
DISTANCE: 30″ — Measure through plane of external auditory meati

CMS. THICKNESS		12	13	14	15	16	17	18	19	20	21
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.
	with medium screens	66	68								
	with Army wafer grid	.	.	70	72	74	76	78	80	82	84
MA - SEC		12					24				

AUXILIARIES: CONE.

Fig. 180.—SKULL, FRONTO-OCCIPITAL





ANATOMICAL: Occipital bone and foramen magnum, petrous ridges, vestibular area and mastoids. Secondarily, internal acoustic meati, dorsum sellae, anterior clinoids.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient supine, chin drawn in; plane through external canthi and external auditory meati perpendicular to film. Upper border of film level with vertex.

FOCAL SPOT: Align to point 7 cm. above glabella, with 30 to 35° angle of principal ray, caudally, principal ray to center of film.

PRECAUTION: Midsagittal plane perpendicular to film.

ADDITIONAL: Grid; immobilization if needed.

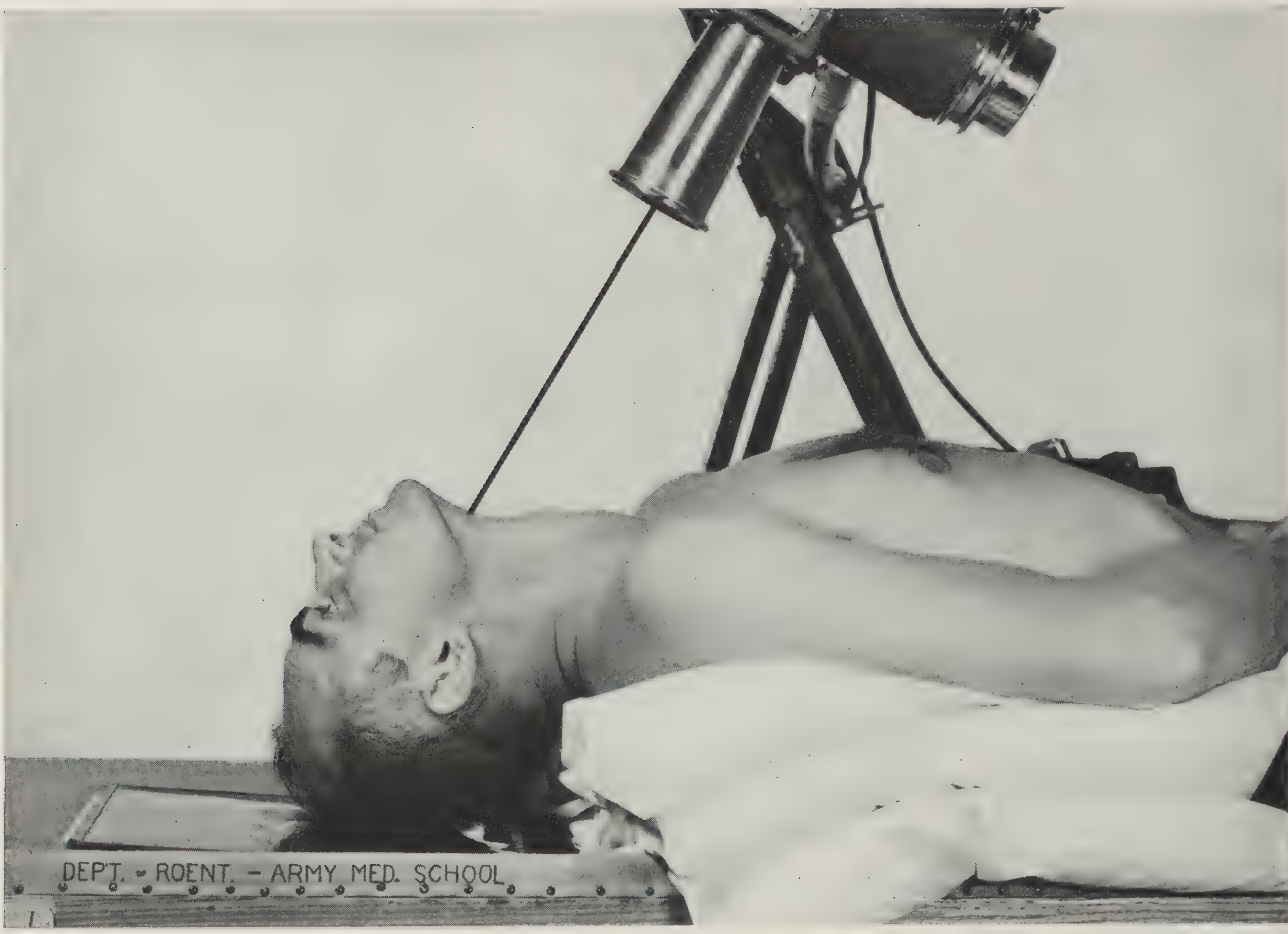
VARIATIONS: Use 45° angulation for foramen magnum and 25° angulation for dorsum sella.

DISTANCE: 30″ — Measure through oblique plane frontal hairline to occiput

		15	16	17	18	19	20	21	22	23	24	25	26
CMS. THICKNESS		15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	70	72	74	76	78	80	82	84	76	78	80	82
MA - SEC						64					128		

AUXILIARIES: CONE for 10 x 12″ coverage.

Fig. 181.—SKULL, SUBMENTOVERTICAL



ANATOMICAL: Foramina at base of skull; sphenoid and posterior ethmoid sinuses; foramen magnum, mandible, etc.

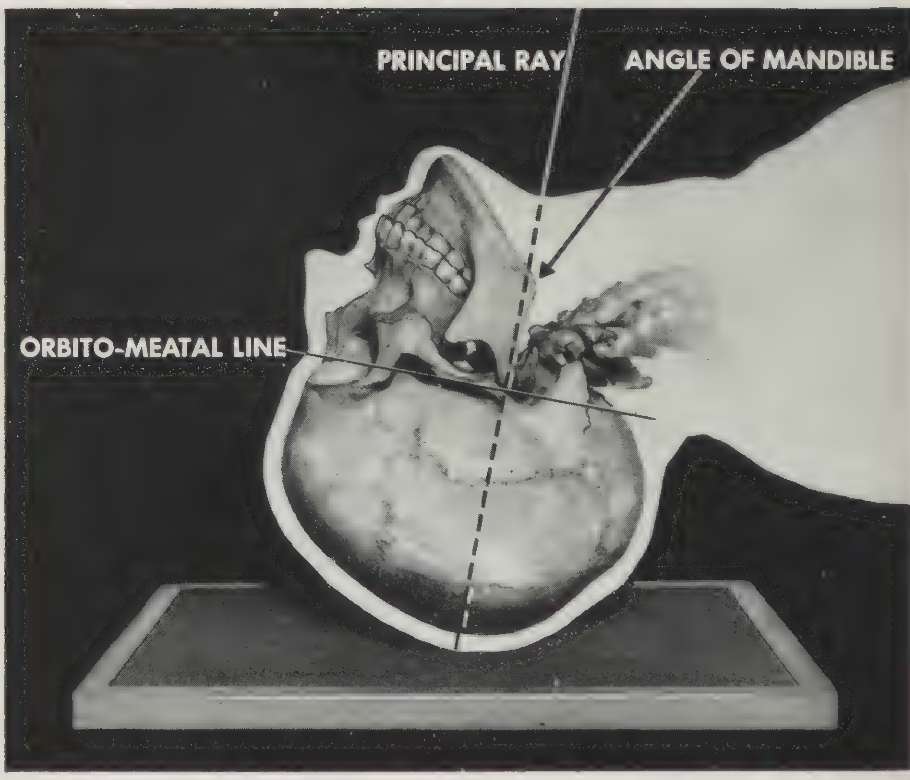
FILM: 10 x 12 inch, lengthwise.

POSITION: Patient supine, back and shoulders elevated, head in extreme extension, vertex centered on film.

FOCAL SPOT: Align to point between mandibular angles, principal ray perpendicular to plane through canthi and external auditory meati, to center of film.

PREÇAUTION: Midsagittal plane perpendicular to film, (ideally, plane through canthi and external auditory meati parallel to film).

ADDITIONAL: Grid; cone (for 10 x 12 inch coverage).

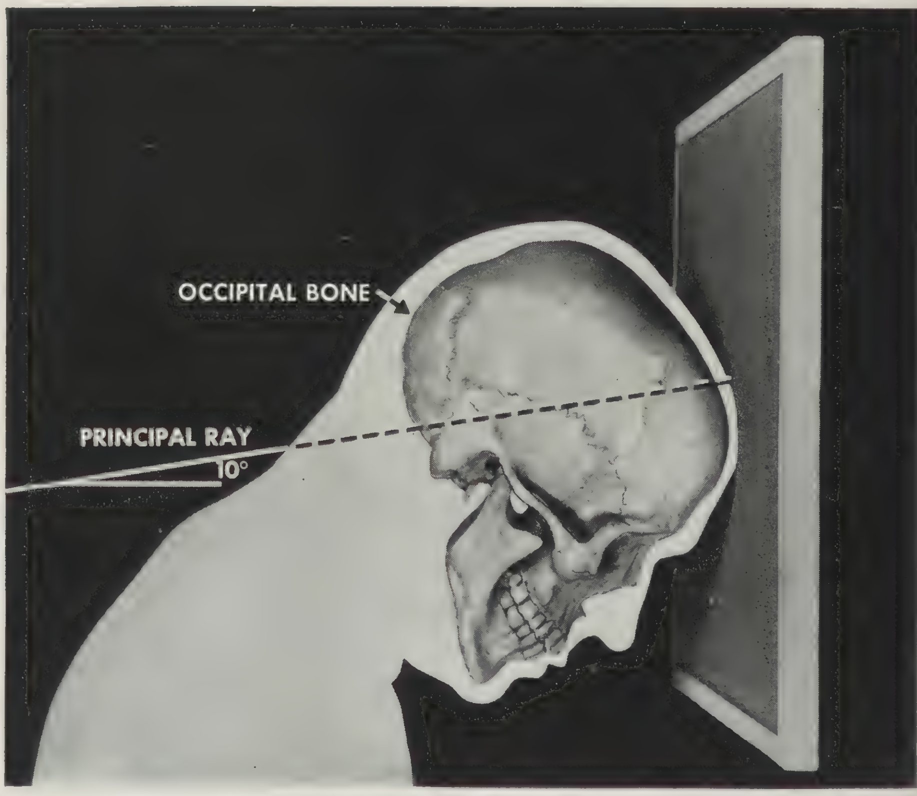


DISTANCE: 30″ — Measure through neck, chin and vertex

CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	72	74	76	78	70	72	74	76	78	80	82	84	76	78	80
MA - SEC			75						150						300	

AUXILIARIES: CONE for 10 x 12″ coverage.

Fig. 182.—SKULL, OCCIPITOFRONTAL



ANATOMICAL: Frontal and occipital bones and foramen magnum.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient upright, neck flexed, frontal region centered to lower half of film.

FOCAL SPOT: Align 6 cm. below occipital protuberance, principal ray angled 10° cephalad to center of film.

PRECAUTION: Midsagittal plane perpendicular to and in midwidth of film.

ADDITIONAL: Grid. Respiration suspended. Immobilization band if needed.

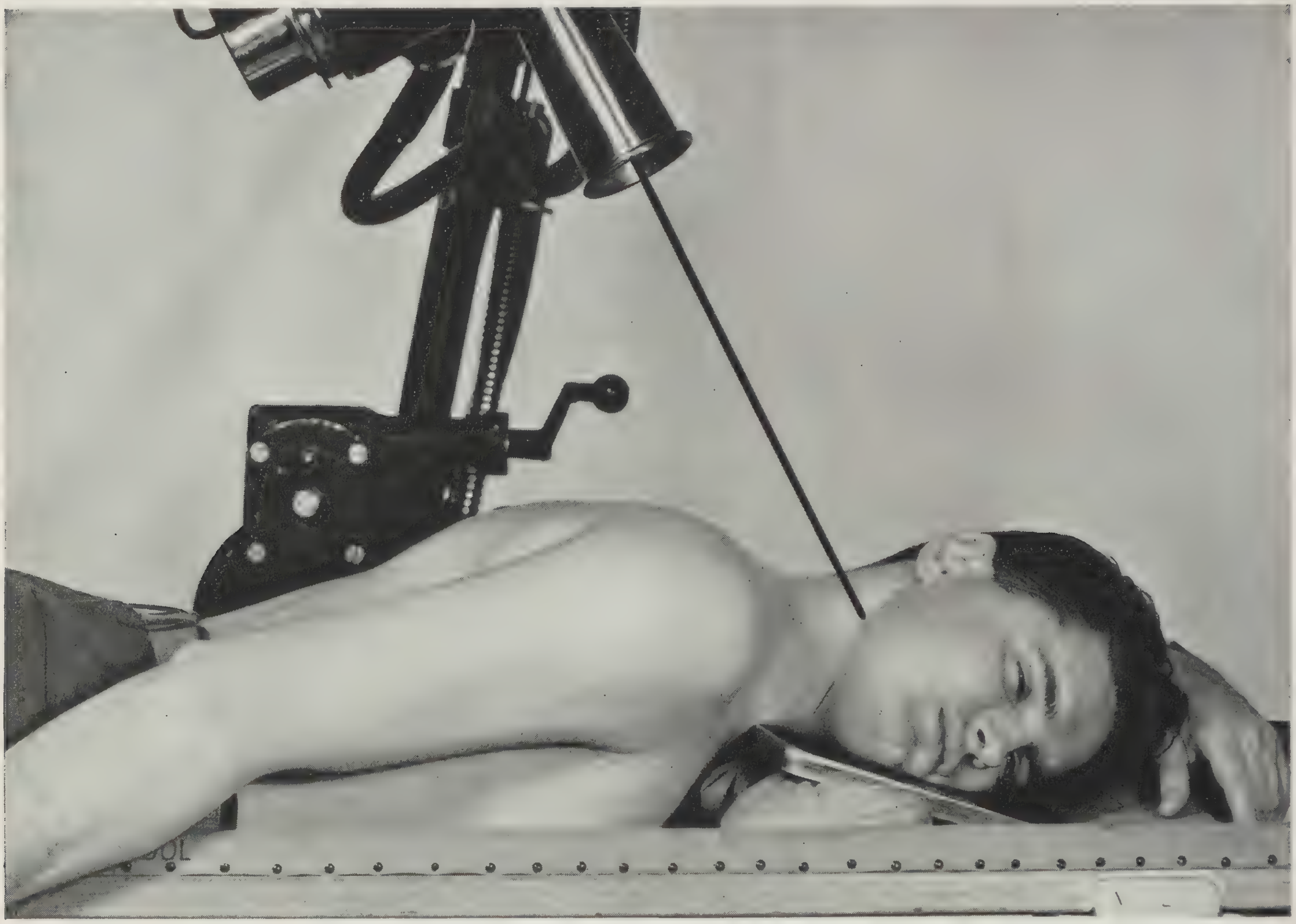
NOTE: Projection may be made with either positioning; the projection may be made fronto-occipitally, instead of occipitofrontally.

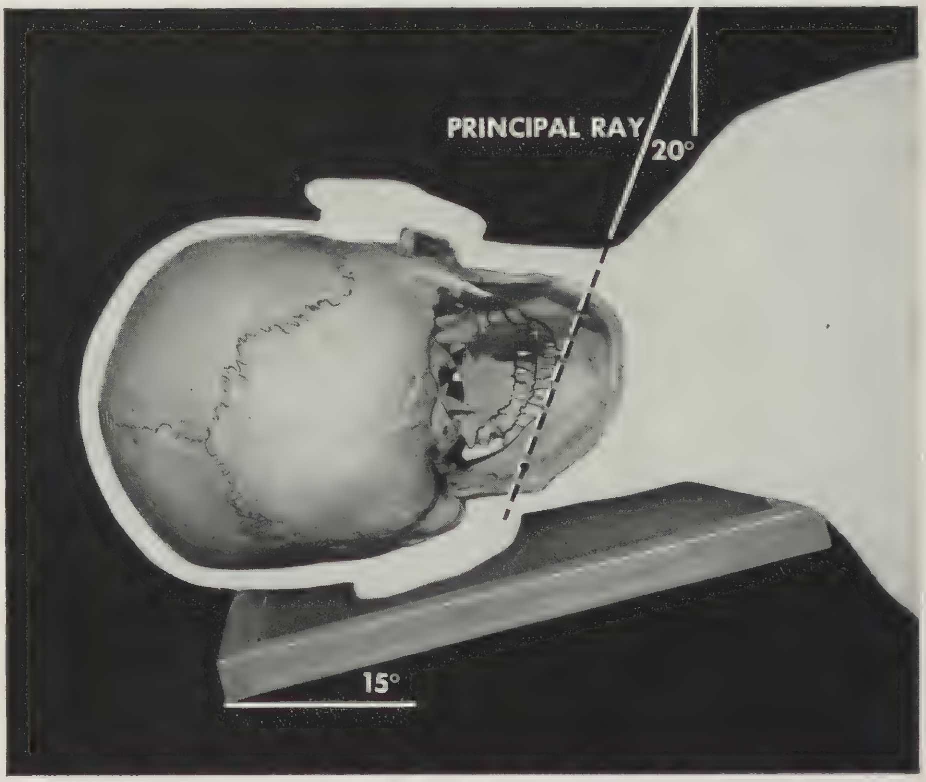
DISTANCE: 30″ Measure through oblique plane 7 cms. above glabella and 3 cms. below external occipital protuberance.

CMS. THICKNESS		15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	70	72	74	76	78	80	82	84	76	78	80	82
MA - SEC		64								128			

AUXILIARIES: CONE for 10 x 12″ coverage.

Fig. 183.—MANDIBLE, LATERAL





ANATOMICAL: Body of mandible, angle, mental foramen; secondarily, lower teeth.

FILM: 8 x 10 inch, widthwise.

POSITION: Patient prone, affected side in contact with cassette, angle of mandible to center of film; lower border of cassette elevated to 15°; head rotated toward side under study (to the extent of facial contour—approximately 15°).

FOCAL SPOT: Align to point 5 cm. below the angle of the mandible remote from film; principal ray directed 20° cephalad to center of film.

PRECAUTION: Dentures, etc., removed.

ADDITIONAL: Cone.

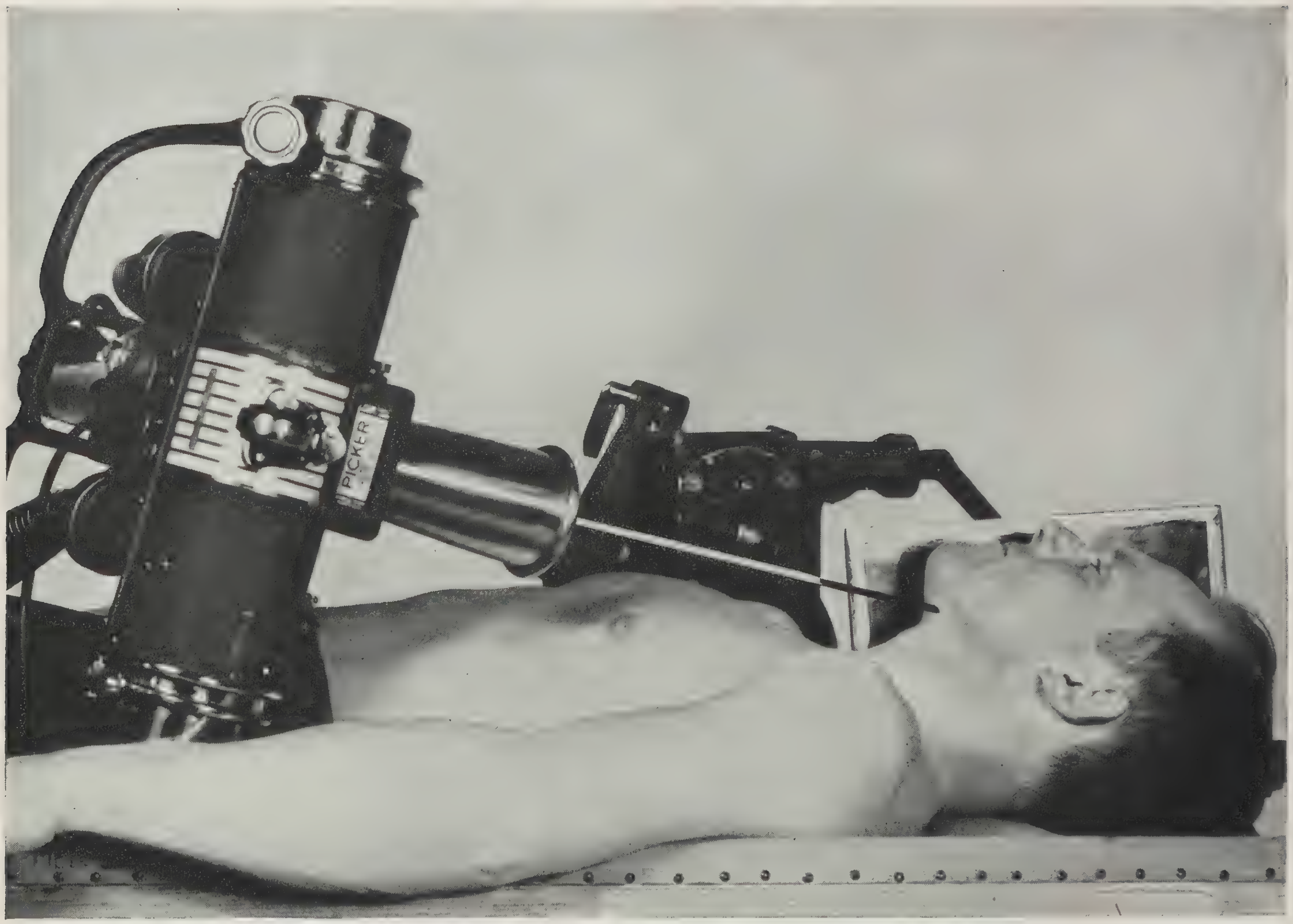
VARIATIONS: Site of particular interest (tooth, etc.) to center of film.

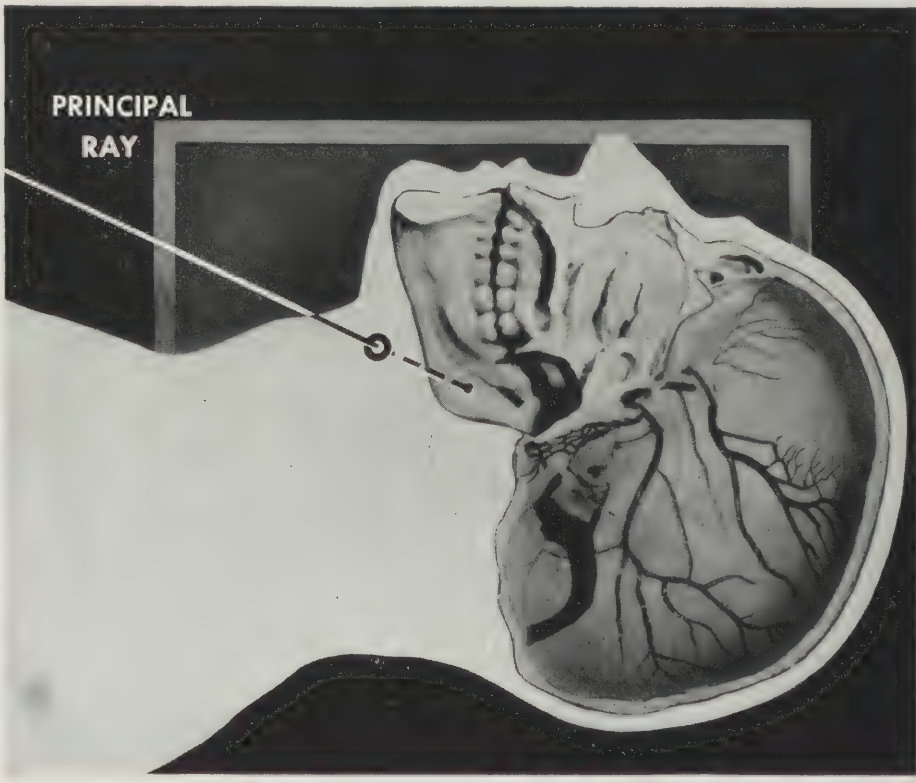
DISTANCE: 30″ — Measure through plane of angles of mandible, laterally

CMS. THICKNESS		11	12	13	14	15	16	17	18
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.
	with medium screens	72	74	76	78	70	72	74	76
	with Army wafer grid	.	.	.	.	.	.	.	.
MA - SEC.		5				10			

AUXILIARIES: CONE.

Fig. 184.—MANDIBLE, LATERAL (recumbent)





ANATOMICAL: Ramus and body of mandible, lower teeth of affected side.

FILM: 8 x 10 inch, vertical, lengthwise.

POSITION: Patient supine, chin slightly extended, angle of mandible at center of film; head rotated to side under study—approximately 15°.

FOCAL SPOT: Align point 3 cm. below the angle of mandible nearer film; principal ray angled 15 to 20° toward the head.

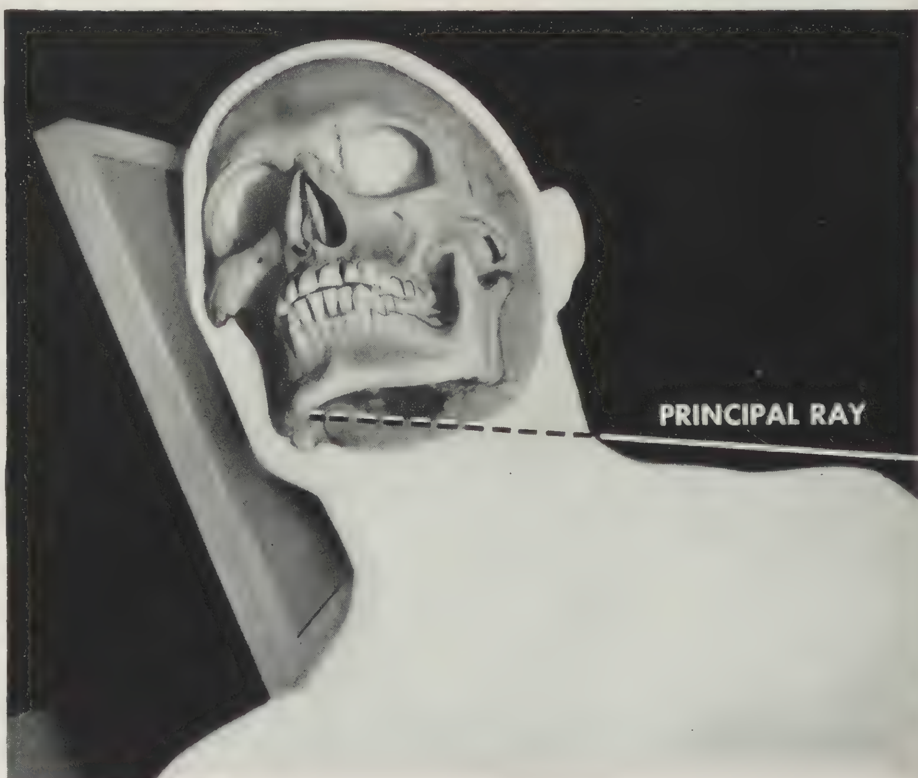
PRECAUTION: Head immobilized by sandbags, respiration suspended.

ADDITIONAL: Cone.

DISTANCE: 30″		Measure through plane of angles of mandible, laterally							
CMS. THICKNESS		11	12	13	14	15	16	17	18
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.
	with medium screens	72	74	76	78	70	72	74	76
	with Army wafer grid	.	.	.	.	.	.	.	.
MA - SEC		5				10			

AUXILIARIES: CONE.

Fig. 185.—MANDIBLE, LATERAL (erect)



ANATOMICAL: See previous position.

FILM: 8 x 10 inch, widthwise.

POSITION: Patient sitting erect holding cassette against the affected mandible, head slightly rotated and flexed toward the affected side.

FOCAL SPOT: Align to point 5 cm. below the angle of mandible nearer the tube.

PRECAUTION: Chin slightly extended. Respiration suspended.

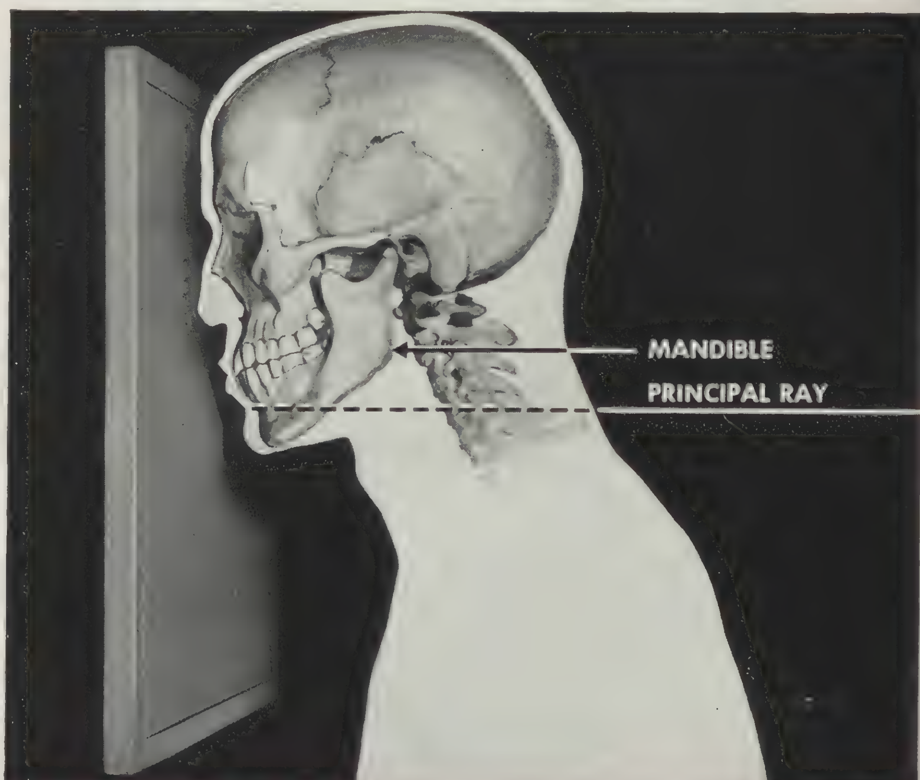
ADDITIONAL: Cone.

DISTANCE: 30″ — Measure through plane of angles of mandible, laterally

CMS. THICKNESS		11	12	13	14	15	16	17	18
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.
	with medium screens	72	74	76	78	70	72	74	76
	with Army wafer grid	.	.	.	.	.	.	.	.
MA - SEC.		5				10			

AUXILIARIES: CONE.

Fig. 186.—MANDIBLE, POSTERO-ANTERIOR (erect—mouth closed)



ANATOMICAL: Symphysis of mandible, rami, coronoid and condylar processes. Secondarily, the lower incisors and canine teeth.

FILM: 8 x 10 inch, lengthwise.

POSITION: Patient erect; mouth closed; forearms resting on thighs; nose and forehead in contact with film (sparing injured part). Mental symphysis to center of film.

FOCAL SPOT: Align principal ray so that it emerges through the mental symphysis.

PRECAUTION: Midsagittal plane perpendicular to film.

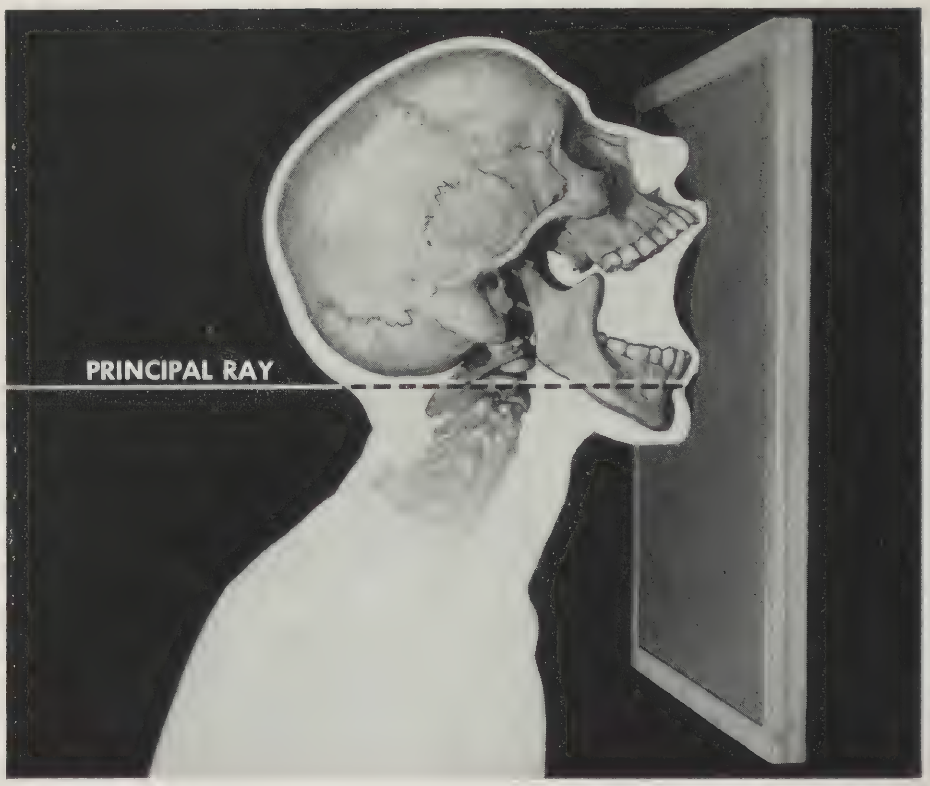
ADDITIONAL: Cone; grid favorable. Projection may be made with patient prone.

DISTANCE: 30″ Measure through plane of principal ray extending through mental symphysis

CMS. THICKNESS		11	12	13	14	15	16	17	18	19	20	21
VARIABLE KVP	with cardboard holders											
	with medium screens											
	with Army wafer grid	72	74	76	78	70	72	74	76	78	80	82
MA - SEC			25						50			

AUXILIARIES: CONE.

Fig. 187.—MANDIBLE, POSTERO-ANTERIOR (erect—mouth open)



ANATOMICAL: As described for previous position.

FILM: 8 x 10 inch, lengthwise.

POSITION: Patient erect, mouth open, supporting cassette against chin and nose. Mental symphysis to center of film.

FOCAL SPOT: Align principal ray horizontally through metal symphysis.

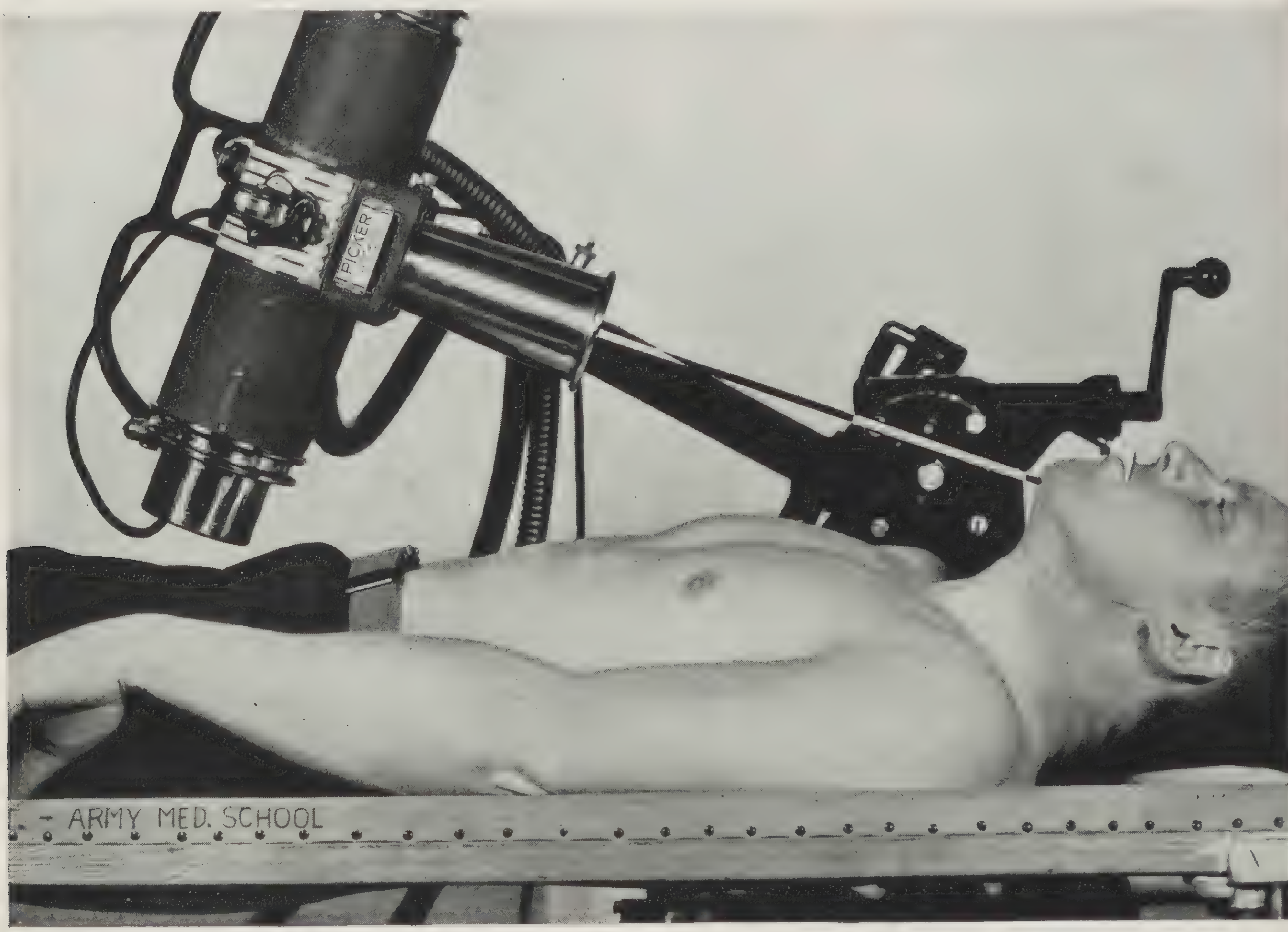
PRECAUTION: Respiration suspended.

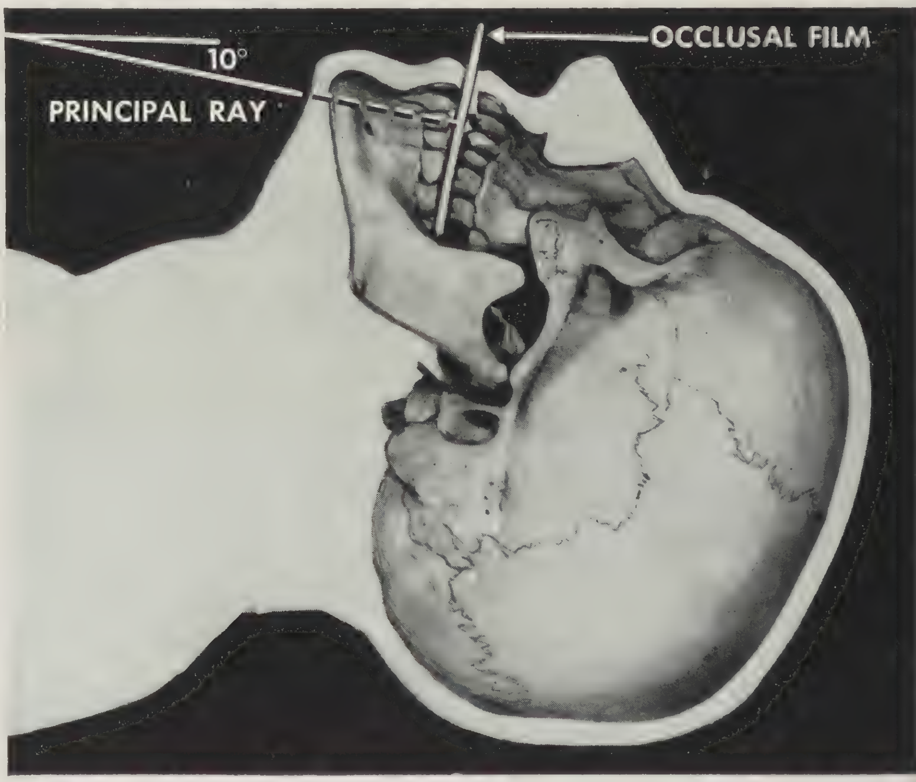
ADDITIONAL: When interested in rami, condylar processes and condyles, cassette and head should be obliqued forward 25 to 40°.

DISTANCE: 30″	Measure through plane of principal ray extending through mental symphysis											
CMS. THICKNESS		11	12	13	14	15	16	17	18	19	20	21
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.
	with medium screens.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	72	74	76	78	70	72	74	76	78	80	82
MA - SEC			25						50			

AUXILIARIES: CONE.

Fig. 188.—MANDIBLE, SYMPHYSIS





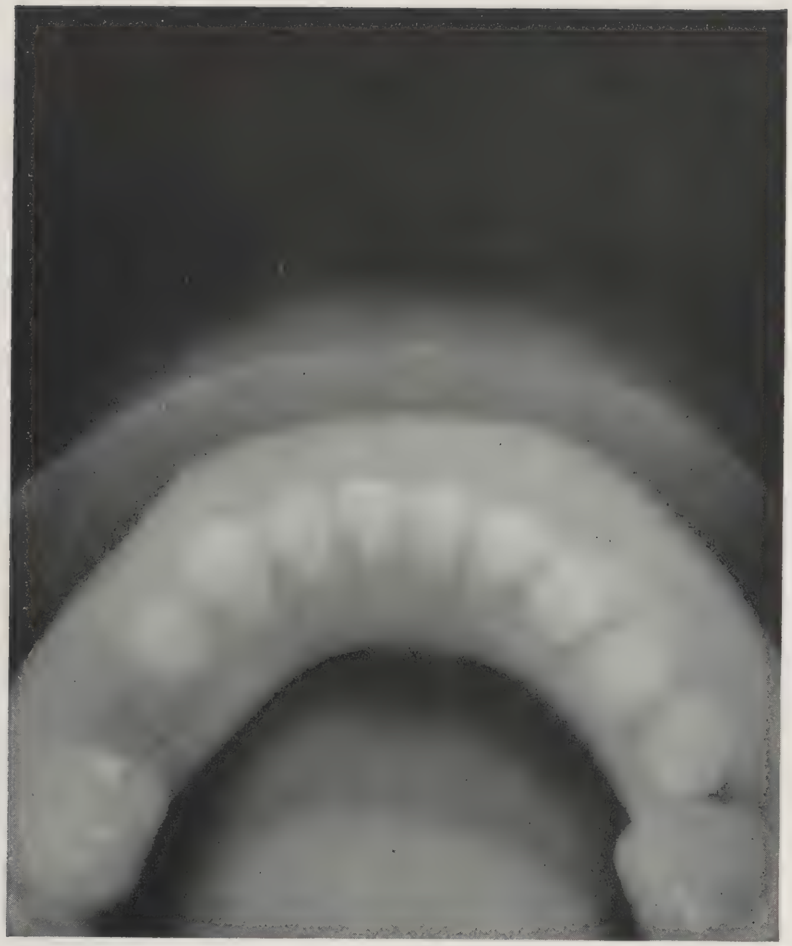
ANATOMICAL: Symphysis of mandible; lower incisors.

FILM: Occlusal film (individual packet) placed in mouth protruding beyond lower lip 1 cm.

POSITION: Patient, supine, head slightly extended, midsagittal plane vertical.

FOCAL SPOT: Align to point posterior aspect of symphysis with principal ray perpendicular to center of film.

PRECAUTION: Respiration suspended.



DISTANCE: 30″	Measure from top of incisor to mental symphysis
CMS. THICKNESS	5 6 7
VARIABLE KVP occlusal film	74 76 78
MA - SEC	120

AUXILIARIES: CONE.

Fig. 189.—MANDIBLE, TEMPOROMANDIBULAR ARTICULATION

ANATOMICAL: Temporomandibular joint; acoustic meati, condyloid process and sella turcica.

FILM: 8 x 10 inch, widthwise; one-half covered with lead mask.

POSITION: Patient prone, midsagittal plane parallel to film. External auditory meatus of side under study to center of outer half of film.

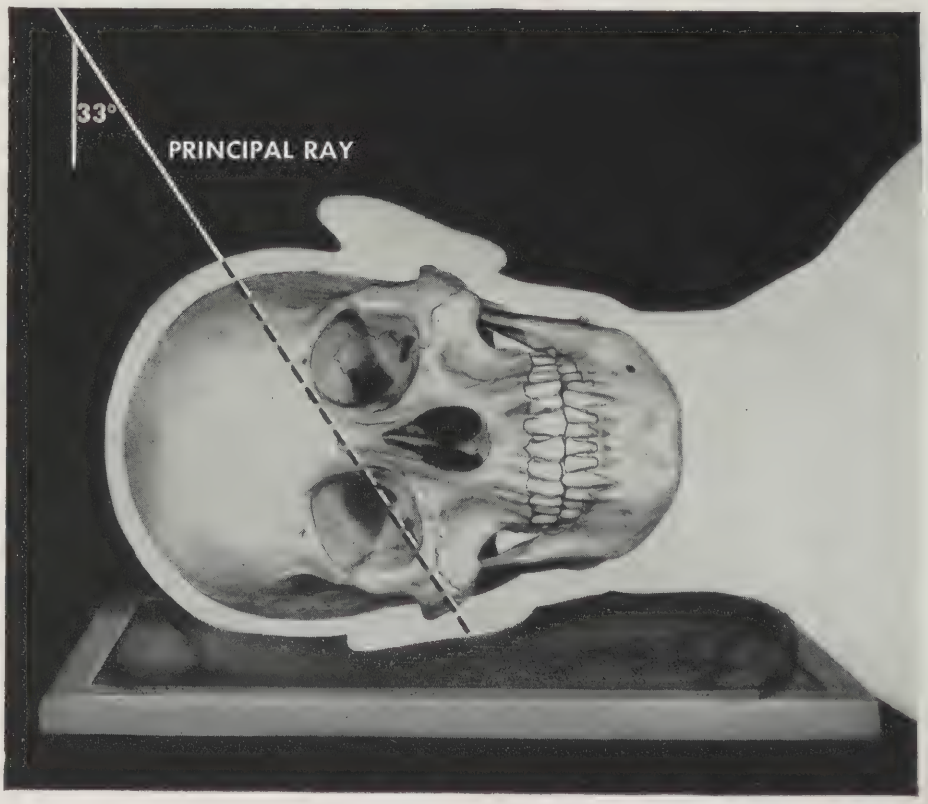
FOCAL SPOT: Align, 7 to 9 cm. above upper temporomandibular articulation. Principal ray directed 33° caudad, emerging at affected articulation.

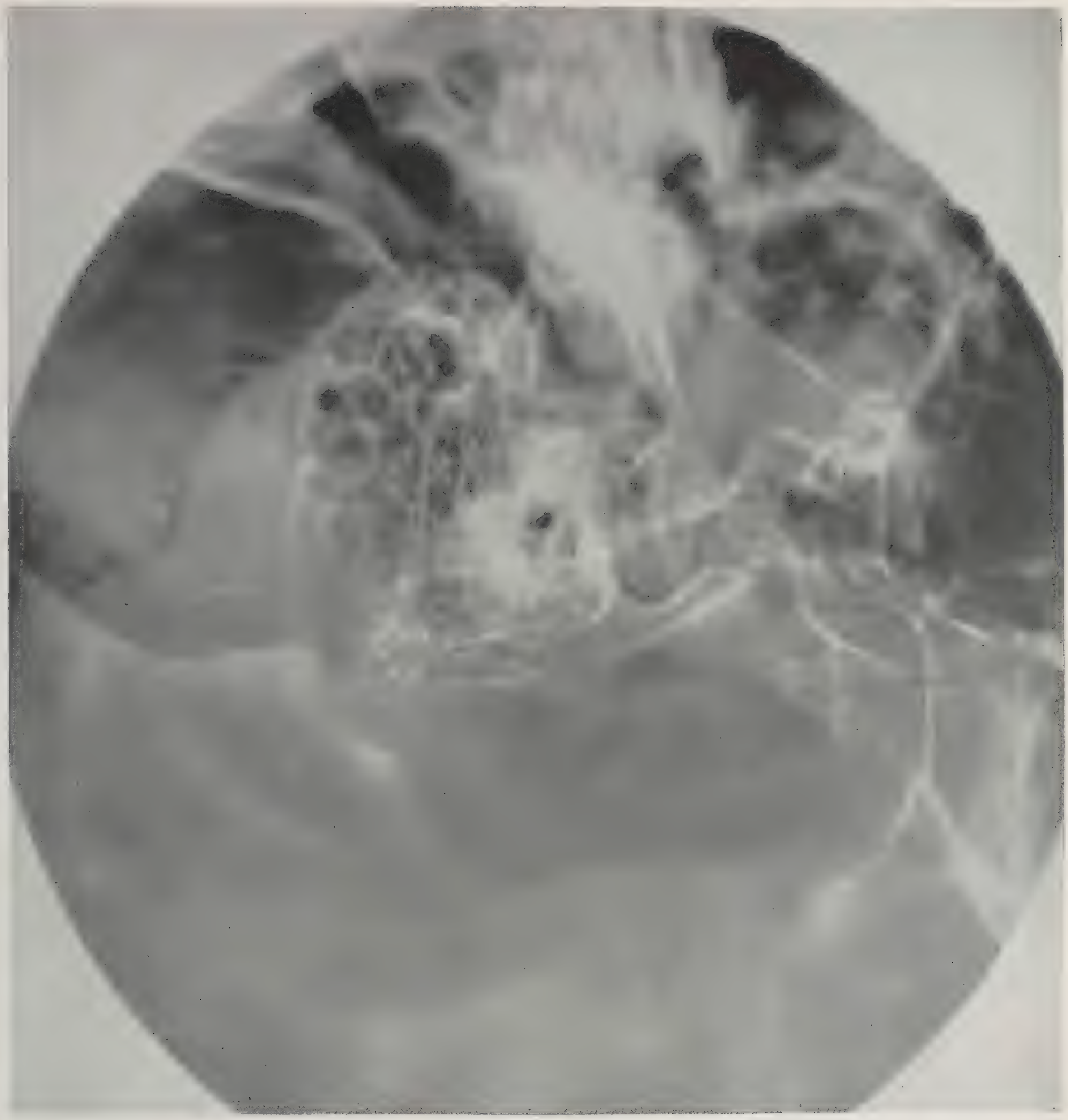
PRECAUTION: Chin slightly extended, supported by fist.

ADDITIONAL: Cone; grid advisable.

VARIATIONS: Complete studies include two views, one with mouth open and one with mouth closed.

NOTE: Two exposures should be made on one film: mouth closed; mouth open.



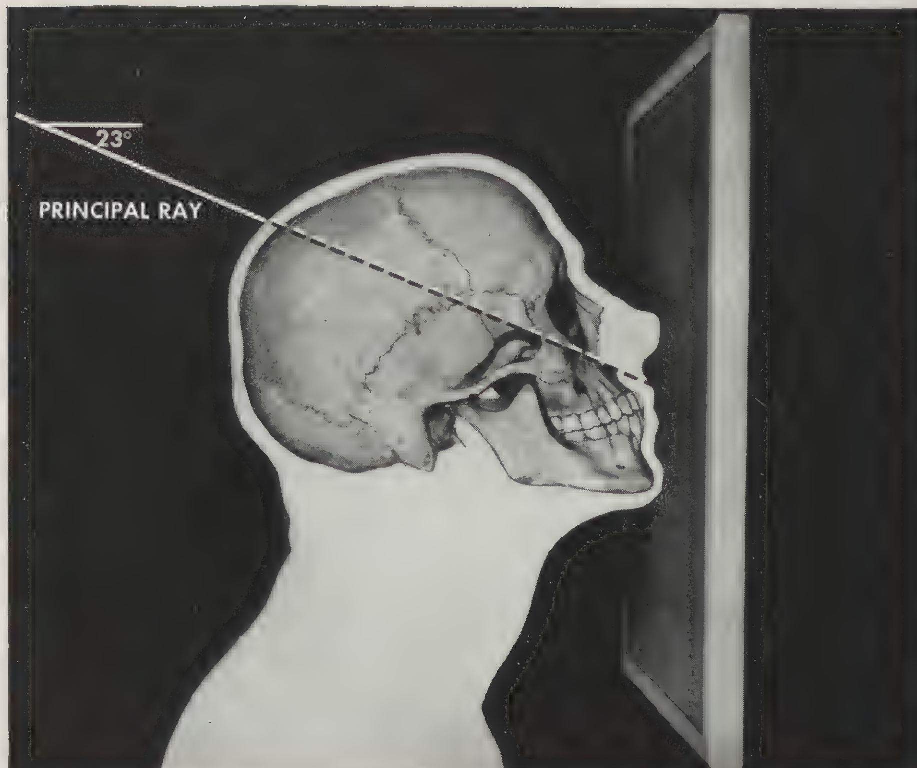


DISTANCE: 30″ — Measure through path of principal ray

CMS. THICKNESS		12	13	14	15	16	17	18	19	20	21
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	66	68	70	72	74	76	78	80	82	84
MA - SEC.		30									

AUXILIARIES: CONE.

Fig. 190.—SKULL, VERTICOSUBNASAL (modified)



ANATOMICAL: Zygomatic arches, maxillae.

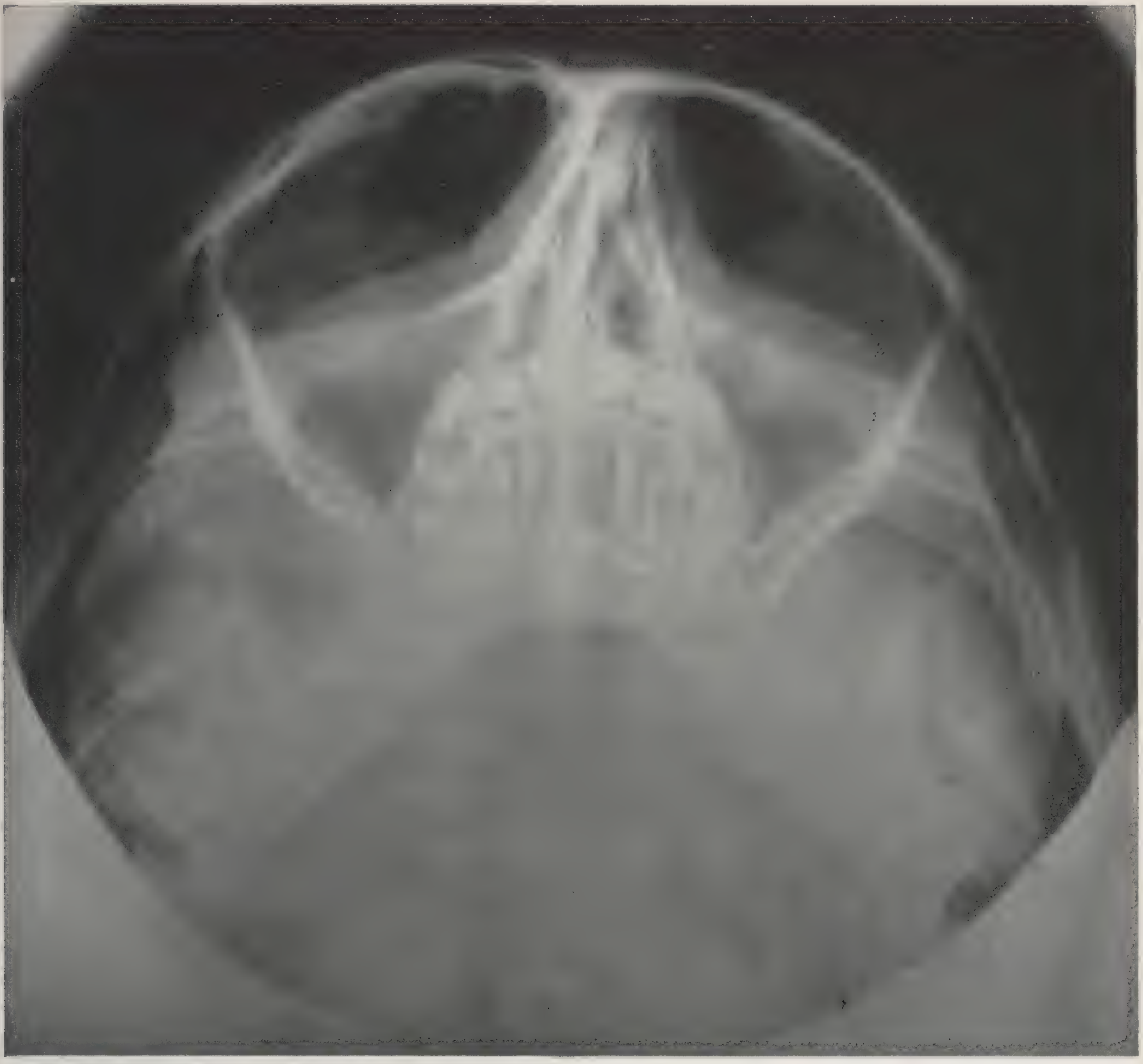
FILM: 10 x 12 inch, lengthwise.

POSITION: Patient upright resting on thighs; nose and chin in contact with cassette; upper lip to its center.

FOCAL SPOT: Align to vertex, principal ray angled 23° caudad, emerging through the middle of the upper lip.

PRECAUTION: Midsagittal plane perpendicular to cassette, interpupillary line parallel to cassette. Respiration suspended.

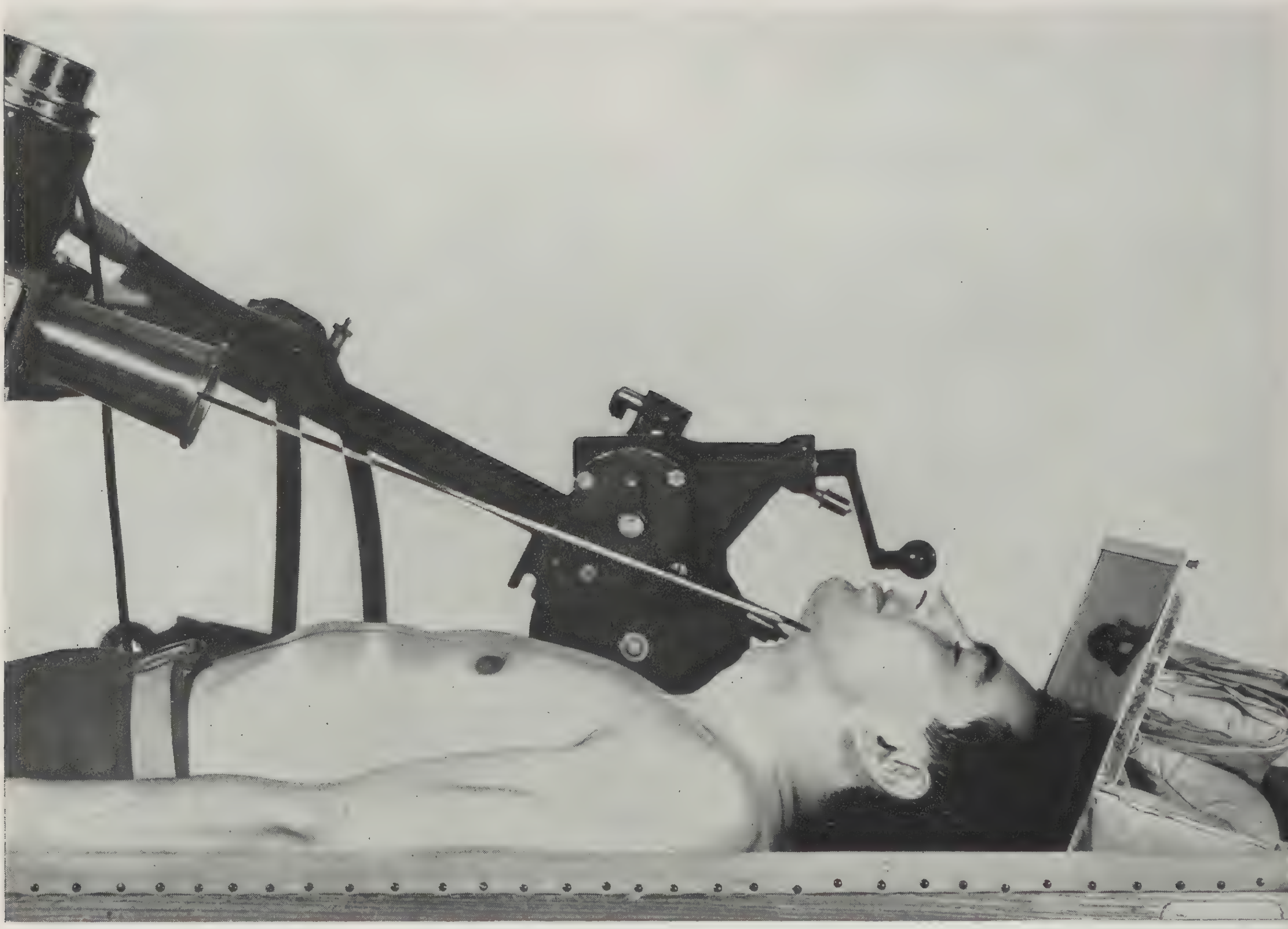
ADDITIONAL: Cone recommended; grid optional.



DISTANCE: 30″													Measure through plane, vertex and nasion
CMS. THICKNESS	14	15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.
VARIABLE KVP with medium screens	58	60	62	64	66	68	70	72	74	76	78	80	82
VARIABLE KVP with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC							50						

AUXILIARIES: CONE.

Fig. 191.—ZYGOMATIC ARCHES, MENTOFRONTAL



ANATOMICAL: Zygomatic arches.

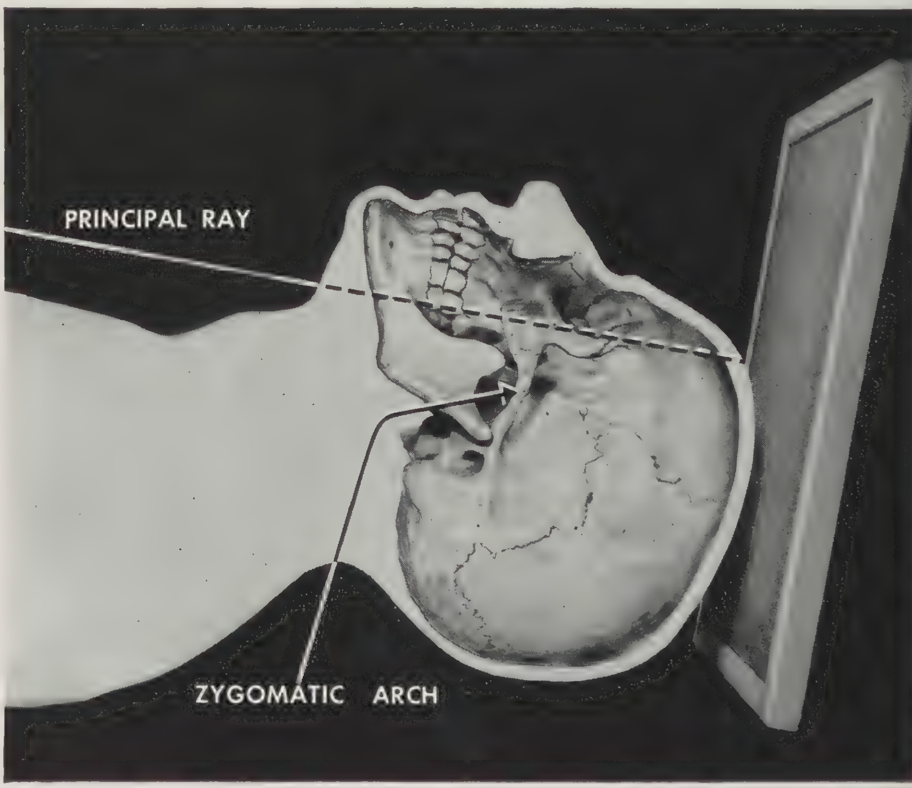
FILM: 10 x 12 inch, 10° tilt from vertical.

POSITION: Patient supine, head extended midsagittal plane vertical and perpendicular to film. Plane of chin and forehead 7 cm. below top of film.

FOCAL SPOT: Align to point 2 to 3 cm. beneath mental symphysis.

PRECAUTION: Head may be elevated on small sandbag.

ADDITIONAL: Immobilization as needed. Grid if desired.

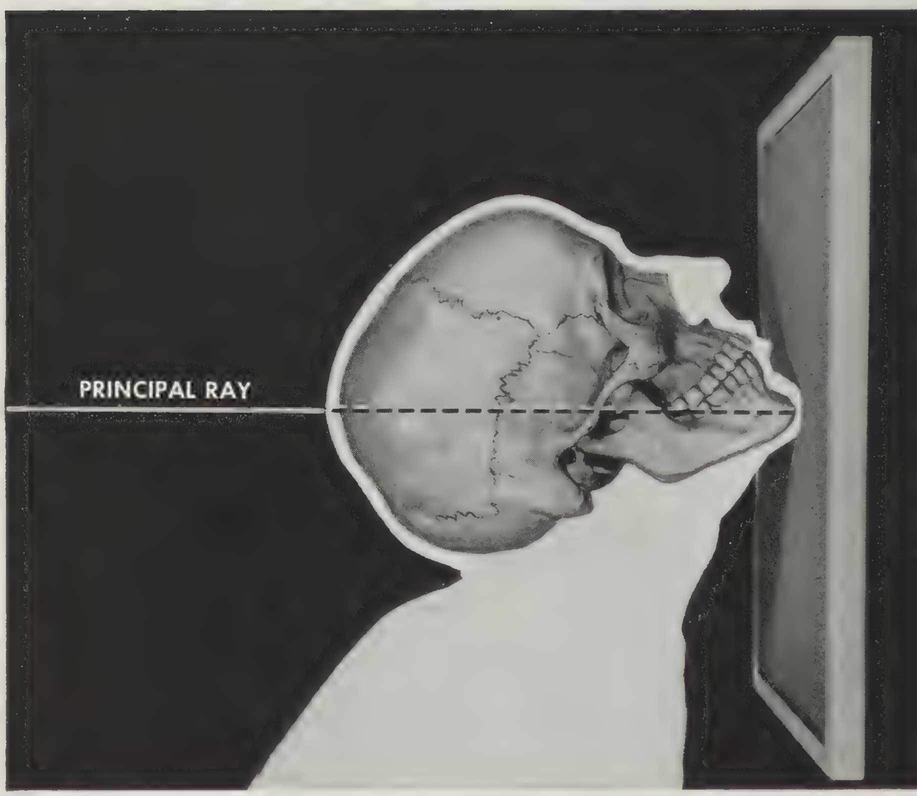


DISTANCE: 30″ — Measure through neck, chin and vertex

CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders															
	with medium screens															
	with Army wafer grid	72	74	76	78	70	72	74	76	78	80	82	84	76	78	80
MA - SEC		38				75								150		

AUXILIARIES: CONE.

Fig. 192.—SKULL, VERTICOSUBMENTAL (erect)



ANATOMICAL: Temporomandibular articulation, processes of the mandibular rami, foramen magnum.

FILM: 10 x 12 inch, lengthwise, vertical.

POSITION: Patient erect; head in maximum extension; tip of chin to center of film; plane of canthi and auditory meati as nearly parallel to film as possible. Midsagittal plane in center of and perpendicular to cassette.

FOCAL SPOT: Principal ray directed horizontally through vertex, emerging through the mental symphysis to center of film.

PRECAUTION: Respiration suspended.

ADDITIONAL: Grid.

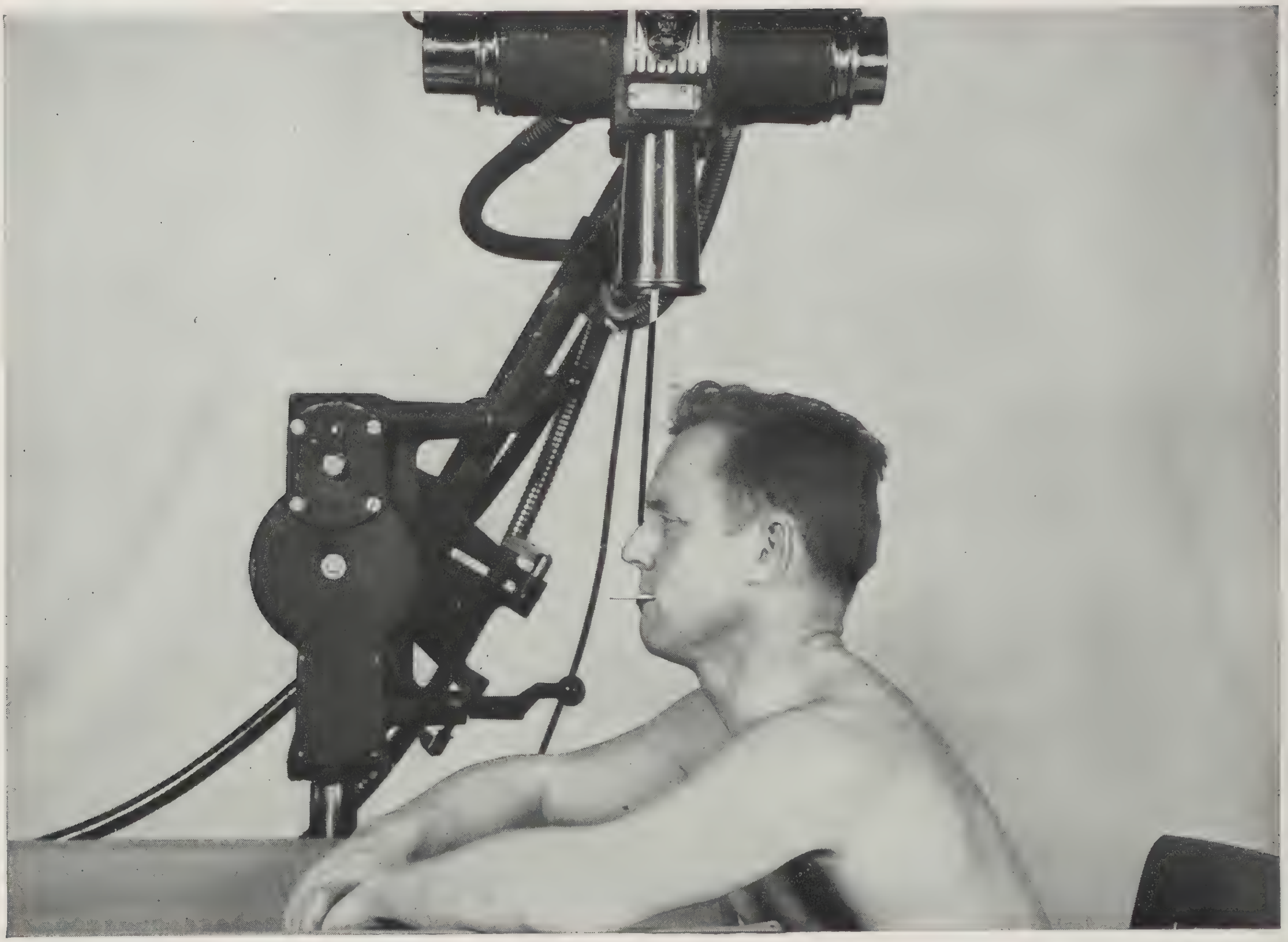
VARIATION: It may be advisable to accomplish this study with patient prone.

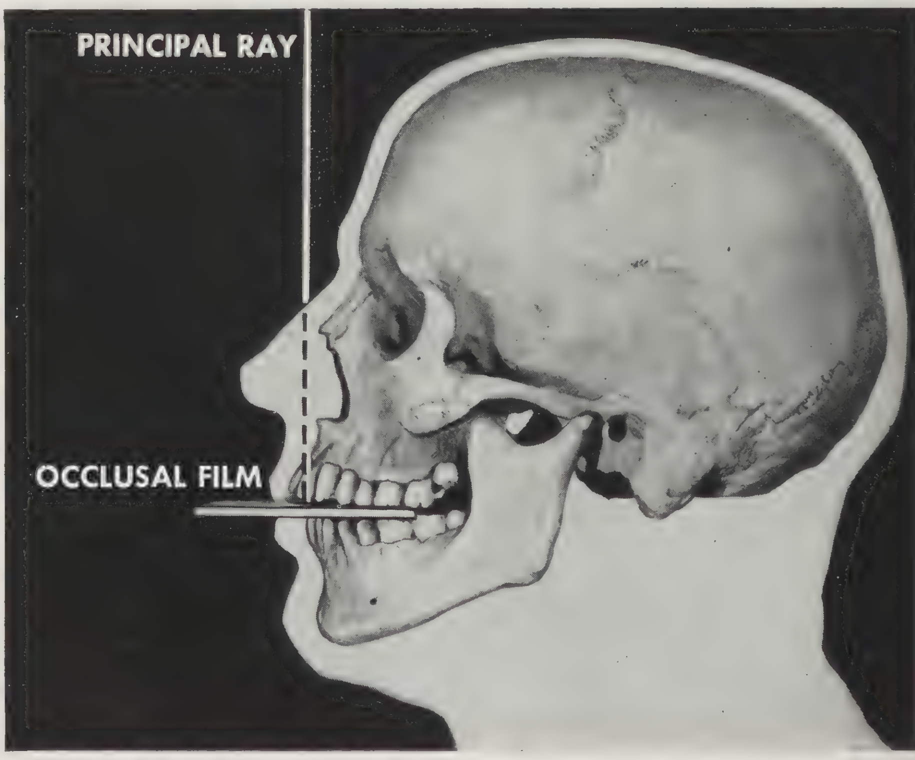
DISTANCE: 30″ — Measure path of principal ray

CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	72	74	76	78	70	72	74	76	78	80	82	84
MA - SEC				75					150				

AUXILIARIES: CONE.

Fig. 193.—NOSE, SUPERO-INFERIOR (intra-oral)





ANATOMICAL: Nasal bones.

FILM: Occlusal film. (Individual packet.)

POSITION: Patient sitting, occlusal film in mouth—3 cm. of film projecting beyond teeth.

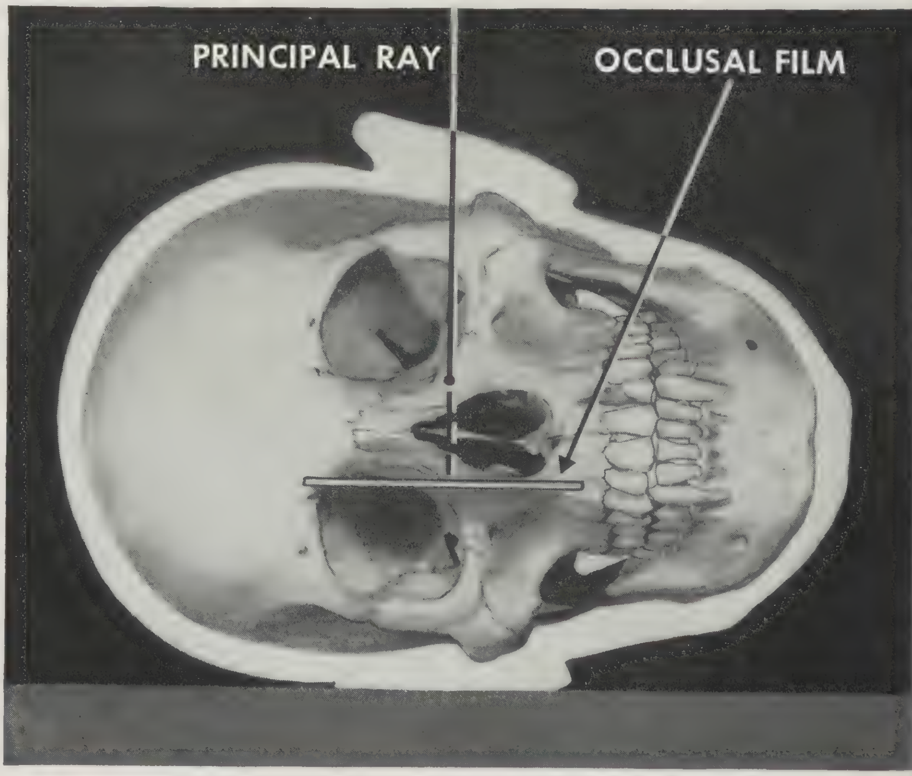
FOCAL SPOT: Align so that principal ray passes just anterior to the forehead and perpendicular to center of film.

PRECAUTION: Midsagittal plane vertical, respiration suspended.

DISTANCE: 30″	Measure through plane from glabella to inferior tip of nose			
CMS. THICKNESS		5	6	7
VARIABLE KVP occlusal film	. . . .	64	66	68
MA - SEC.	. . . .		60	

AUXILIARIES: CONE.

Fig. 194.—NOSE, LATERAL



ANATOMICAL: Nasal bones.

FILM: Occlusal film (or dental film in individual packet).

POSITION: Patient may be prone or sitting erect, holding film against lateral surface of nose, extending well into the internal canthus of the eye, film being in sagittal plane.

FOCAL SPOT: Align to center of lateral surface of nose.

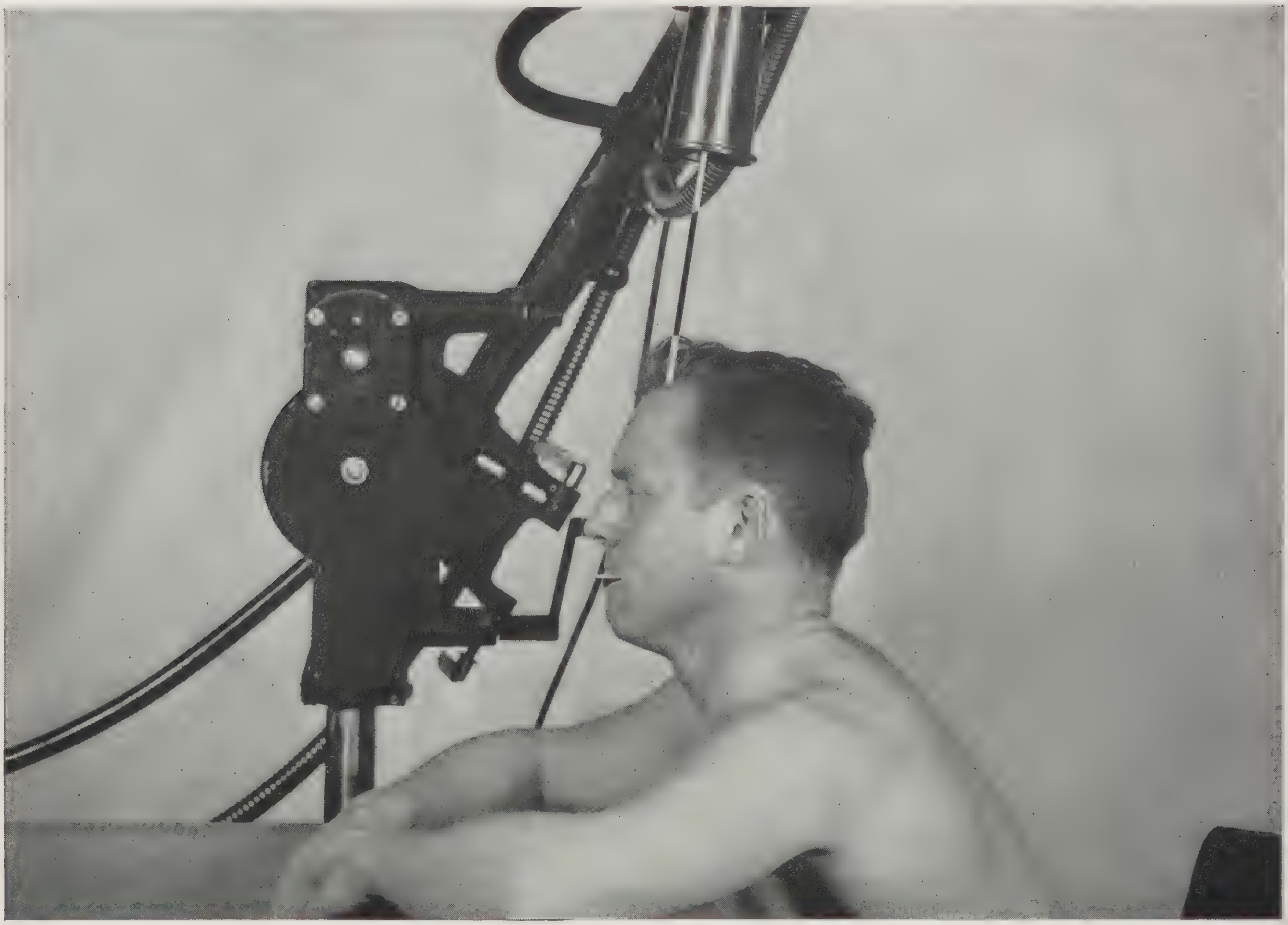
PRECAUTION: Principal ray perpendicular to midsagittal plane and to center of film. Film in close apposition and supported beneath nose and hand.

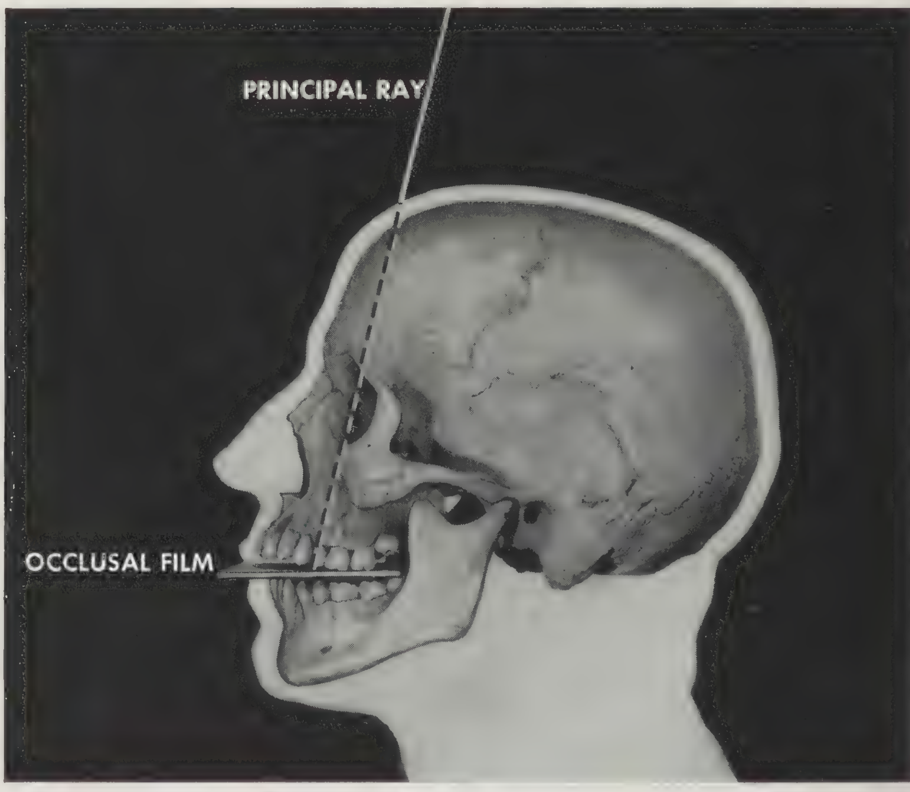
ADDITIONAL: If above films are not available, 8 x 10 inch cardboard holder placed beneath head may be used, being adjusted as for position of lateral skull and centering about 7 cm. anterior to tip of nose.

NOTE: Both sides advisable.

DISTANCE: 30″	Measure through center of bridge of nose			
CMS. THICKNESS	1	2	3	4
VARIABLE KVP occlusal film	54	56	58	60
MA - SEC.	90			
AUXILIARIES: CONE.				

Fig. 195.—MAXILLA, SUPERO-INFERIOR (intra-oral)





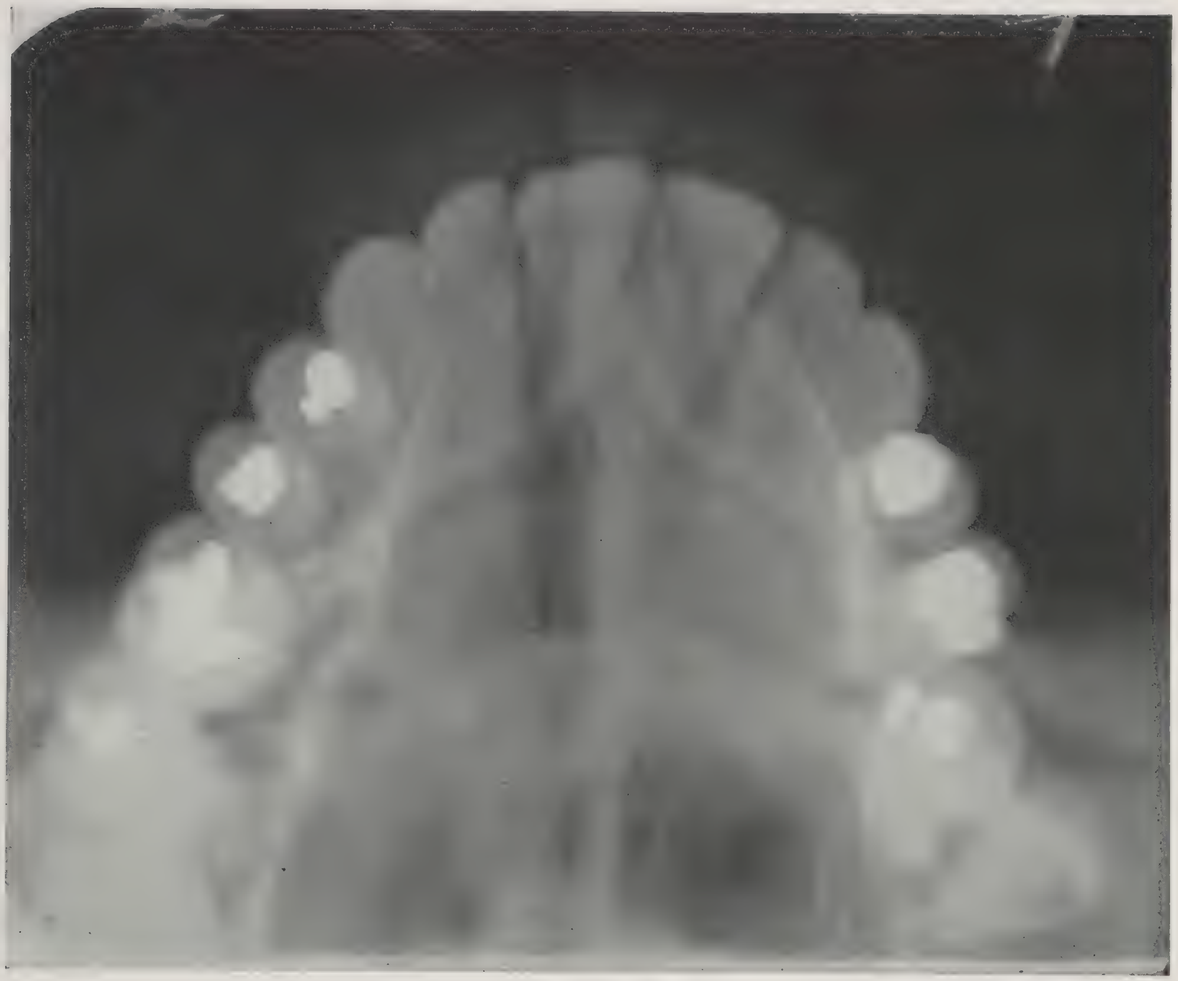
ANATOMICAL: Palatine processes of maxillae.

FILM: Occlusal film (individual packet).

POSITION: Patient sitting erect, occlusal plane horizontal.

FOCAL SPOT: Align to point midway between zygomatic prominences (i.e., midpoint of hair line) to center of film.

PRECAUTION: Cassette advantageous; impose relaxation.



DISTANCE: 30″ — Measure plane through incisor level and vertex						
CMS. THICKNESS	18	19	20	21	22	23
VARIABLE KVP occlusal film	70	72	74	76	78	80
MA - SEC.	125					

AUXILIARIES: CONE.

Fig. 196.—PARANASAL SINUSES: NOSE—FOREHEAD POSITION

ANATOMICAL: Frontal sphenoid and ethmoid sinuses; orbits. Secondarily, vomer, petrous ridges.

FILM: 8 x 10 inch, lengthwise.

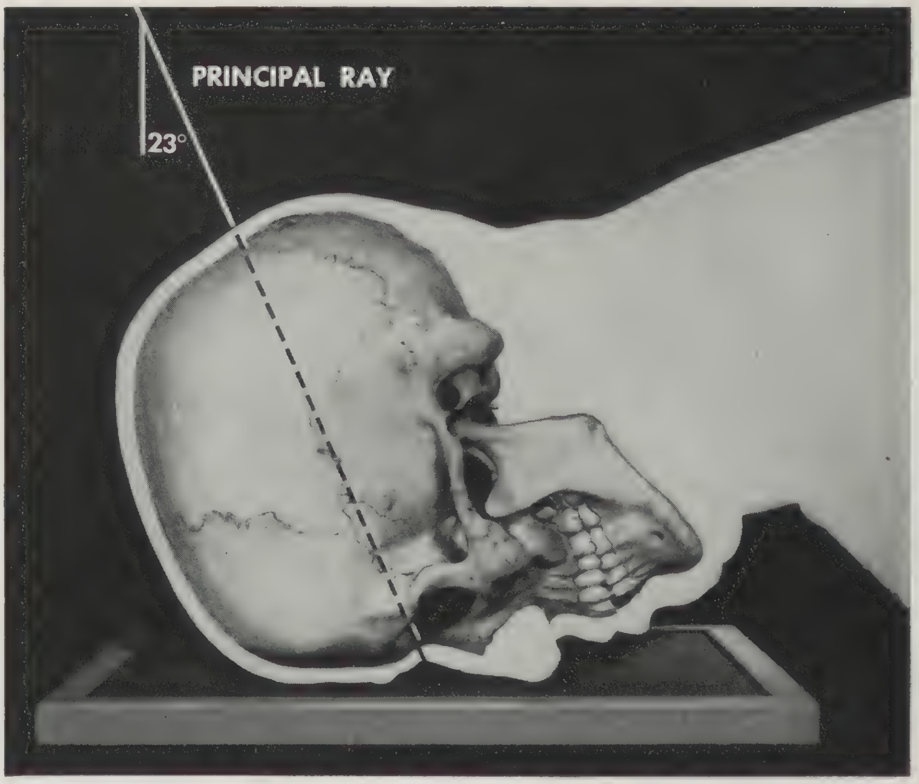
POSITION: Patient prone, forearms flexed beneath chest, nose and forehead in contact with cassette, nasion at center of film.

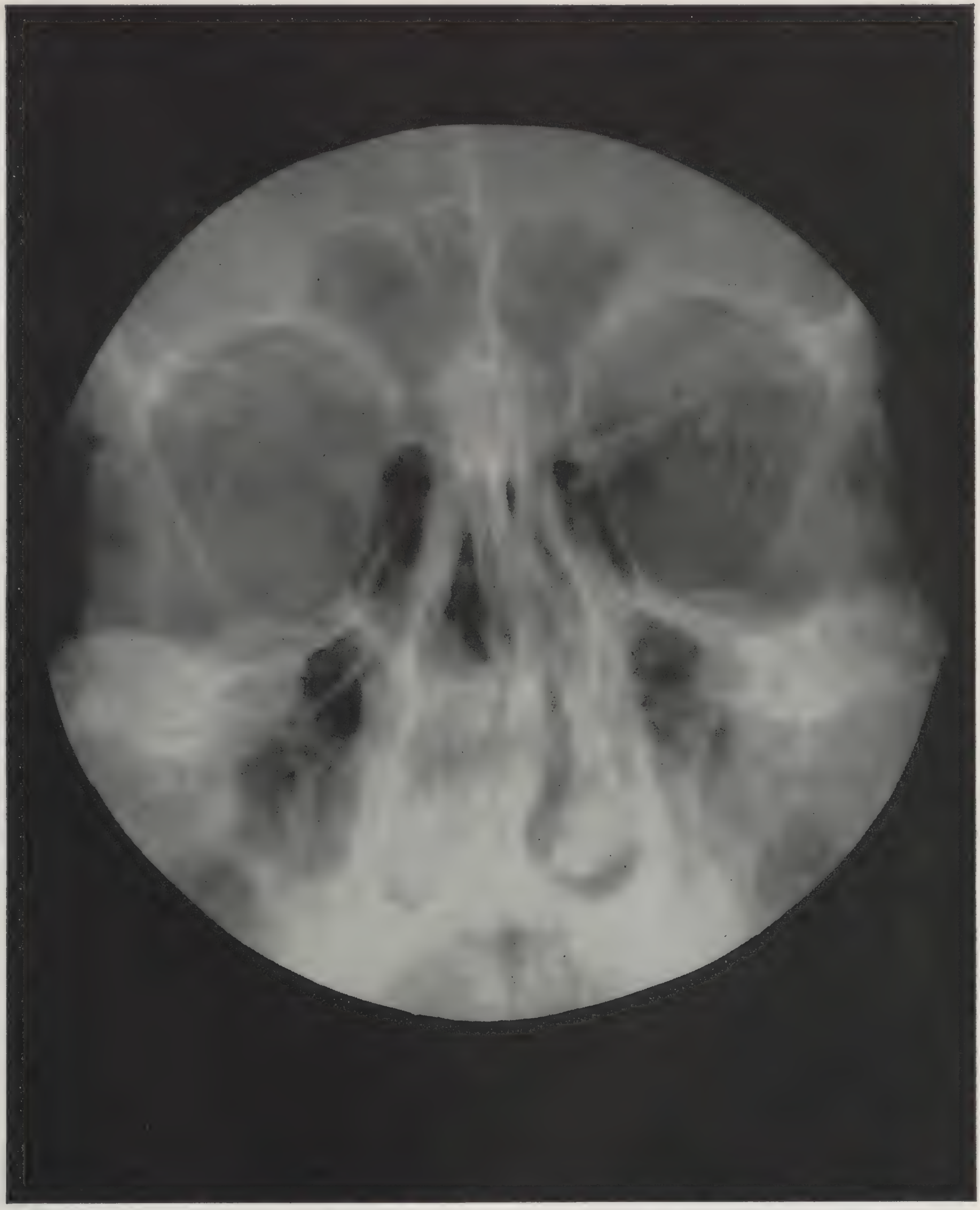
FOCAL SPOT: Align to occiput, principal ray directed 23° caudad to emerge at nasion at center of film.

PRECAUTION: Midsagittal plane perpendicular to film. Suspended respiration.

ADDITIONAL: Cone. Grid optional.

VARIATION: Petrous ridges may be visualized through orbits by angling principal ray only 10° to 15° caudad.



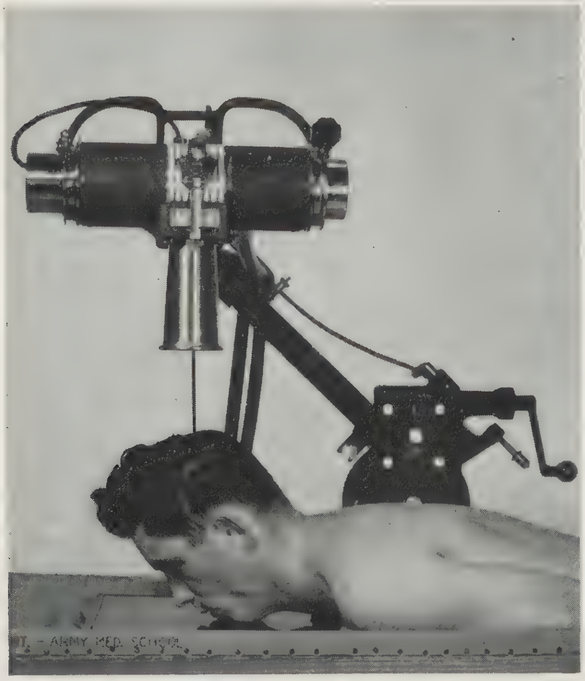


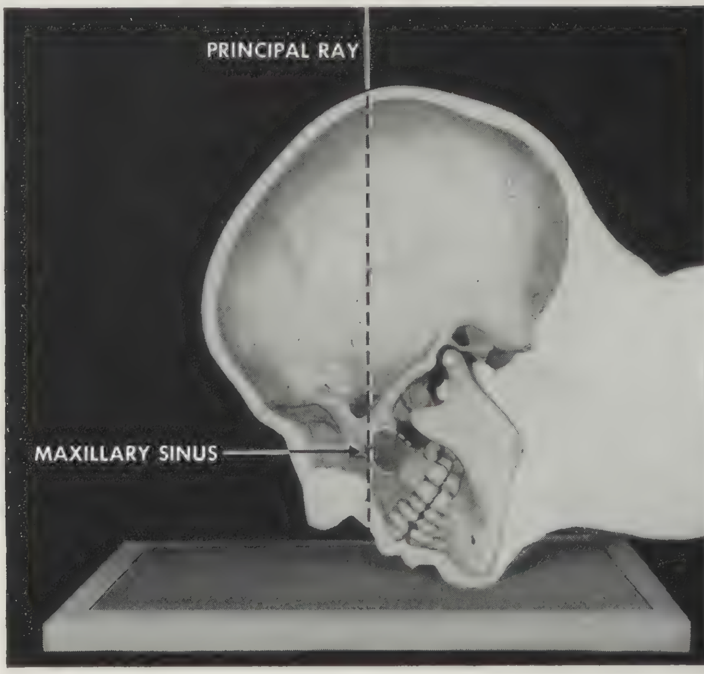
DISTANCE: 20″ Measure along path of principal ray

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	64	66	68	70	72	74	76	78	80	72	74	76	78
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC						12						24		

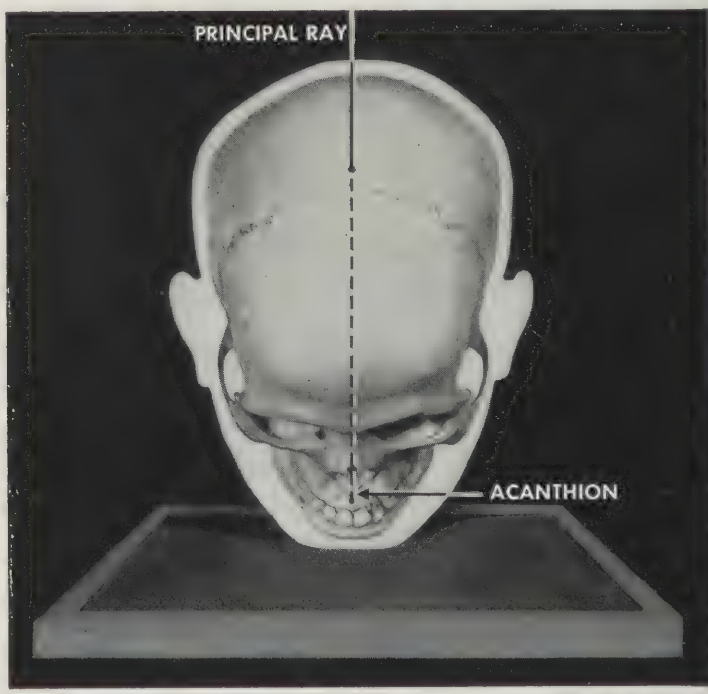
AUXILIARIES: CONE.

Fig. 197.—PARANASAL SINUSES: NOSE—CHIN POSITION (prone)





ANATOMICAL: Maxillary sinuses, anterior versus posterior ethmoids and frontal sinuses. Secondarily, zygomatic arches, orbits and nasal passages.
FILM: 8 x 10 inch, lengthwise.
POSITION: Patient prone, arms flexed beneath chest, chin on cassette, tip of nose 2 cm. from cassette, nasolabial junction over center of film.
FOCAL SPOT: Align so principal ray emerges through nasolabial junction, to center of film.
PRECAUTION: Dentures, hairpins, etc., removed. Midsagittal plane perpendicular to film. Suspended respiration.
ADDITIONAL: Cone; grid optional. Fixation band advisable.
VARIATION: Petrous ridges may be projected to lower level by moving tube cephalad and projecting principal ray 10° caudad.

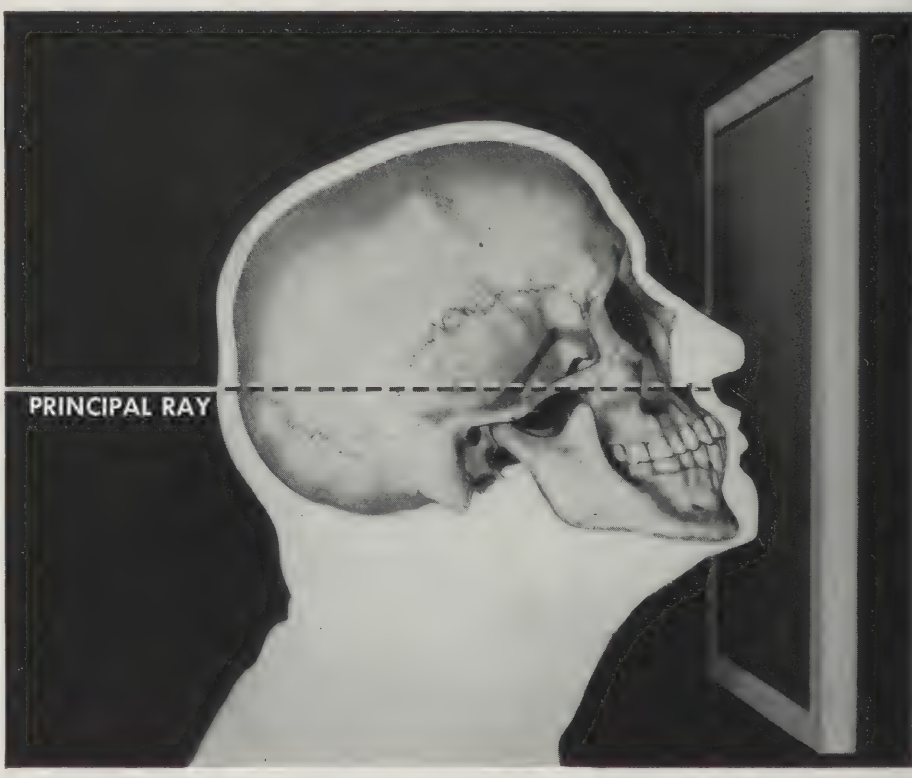


DISTANCE: 20″ — Measure through plane of superior occiput and acanthion

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	58	60	62	64	66	68	70	72	74	76	78	80	82
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC		30												

AUXILIARIES: CONE.

Fig. 198.—PARANASAL SINUSES: NOSE—CHIN POSITION (erect)



ANATOMICAL: Same structures as indicated in preceding position.

FILM: 8 x 10 inch, lengthwise.

POSITION: Patient sitting, chin resting against cassette; tip of nose 2 cm. from cassette.

FOCAL SPOT: Align to vertex, principal ray to emerge through nasolabial junction to center of film.

PRECAUTION: Dentures, hairpins, etc., removed. Midsagittal plane vertical. Suspended respiration.

ADDITIONAL: Cone; grid optional. Immobilization band with vertical cassette holder advisable.

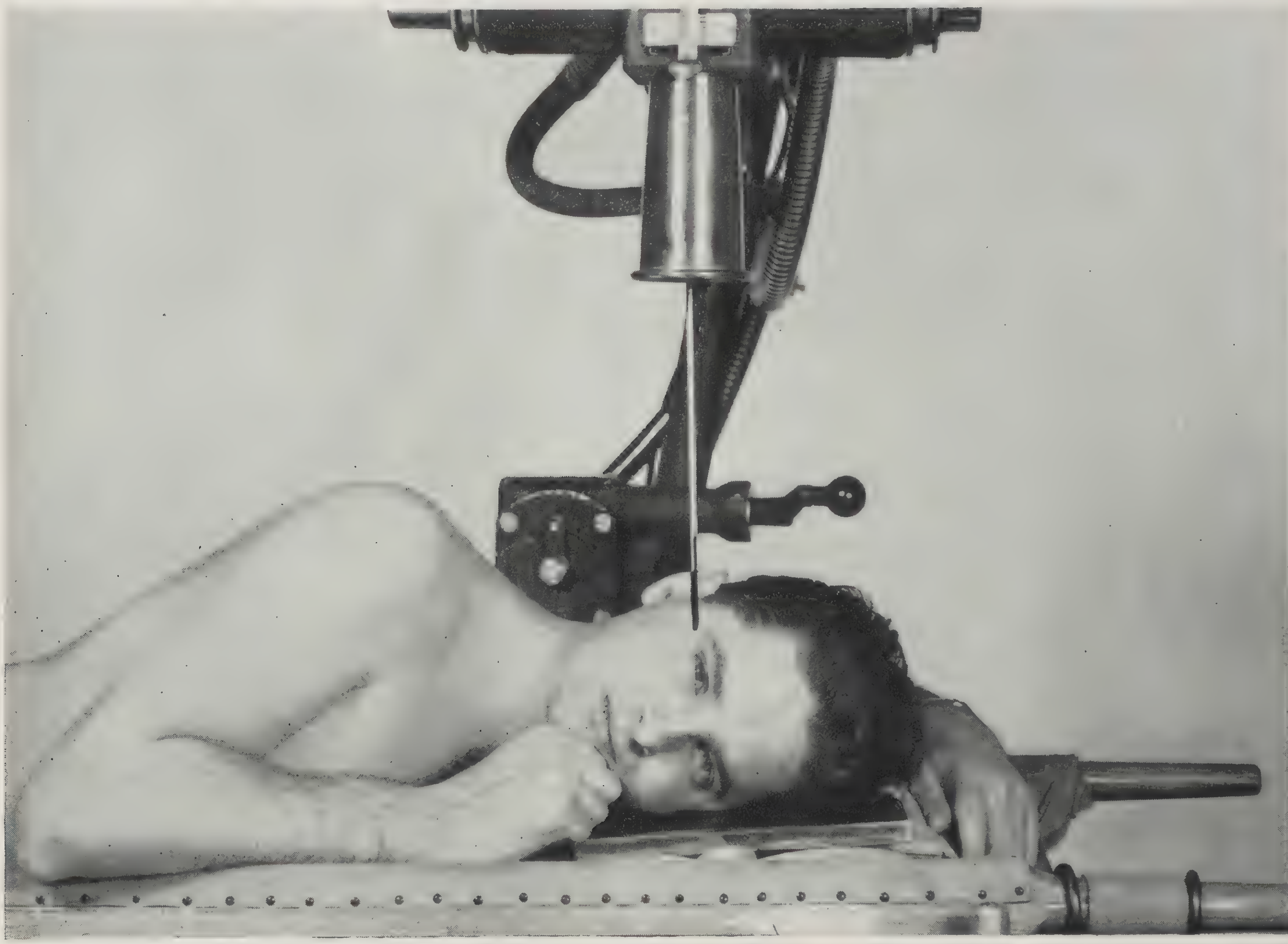
VARIATION: Fluid level may be demonstrated by re-examination with head tilted 45° to either side, other factors remaining the same.

DISTANCE: 20″ — Measure through plane of superior occiput and acanthion

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	58	60	62	64	66	68	70	72	74	76	78	80	82
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC								30						

AUXILIARIES: CONE.

Fig. 199.—PARANASAL SINUSES, LATERAL



ANATOMICAL: Frontal sphenoid and ethmoid sinuses. Secondarily, antra, floor of anterior cranial fossa, sella turcica.

FILM: 8 x 10 inch, lengthwise.

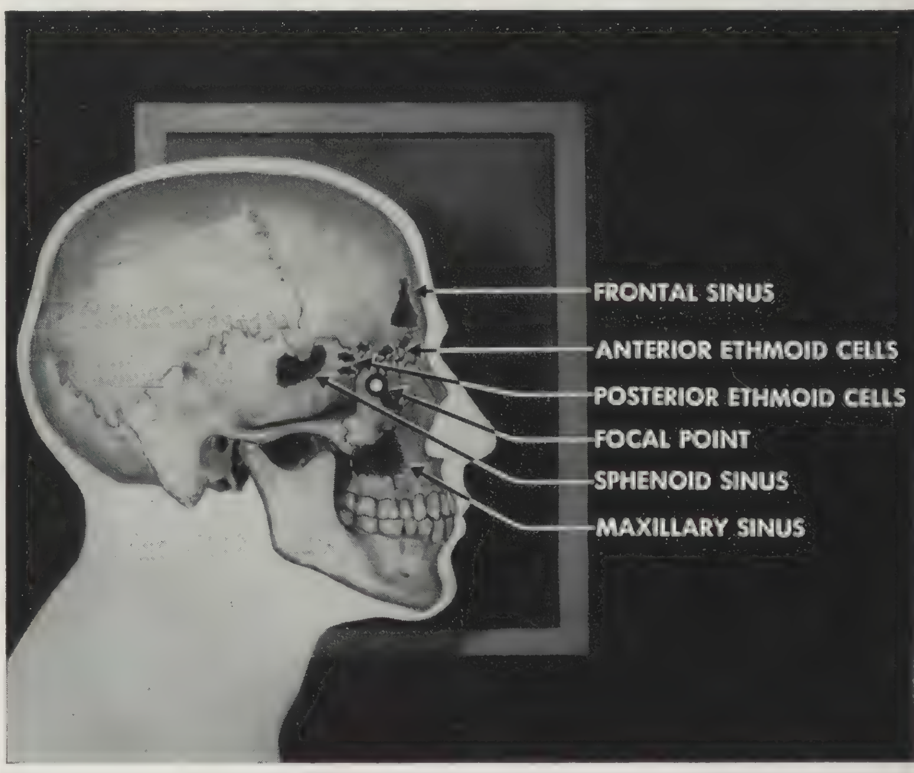
POSITION: Patient prone, head turned with midsagittal plane parallel with cassette. External canthus at center of film. Chin supported.

FOCAL SPOT: Align principal ray to external canthus to center of film.

PRECAUTION: Dentures, hairpins, etc., removed. Plane through canthi perpendicular to film. Respiration suspended.

ADDITIONAL: Cone. Grid optional.

VARIATIONS: Sphenoidal sinus better visualized by centering to point 3 cm. anterior to auditory meatus. Erect position may be used by having patient support cassette on shoulder.



DISTANCE: 20″ — Measure through plane of outer canthus

CMS. THICKNESS		12	13	14	15	16	17	18	19	20	21
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.
	with medium screens	66	68	70	72	74	76	78	80	82	84
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.
MA - SEC		6									

AUXILIARIES: CONE.

Fig. 200.—PARANASAL SINUSES: ORBITAL POSITION

ANATOMICAL: Posterior ethmoidal and sphenoid sinuses; optic foramen.

FILM: 8 x 10 inch, widthwise.

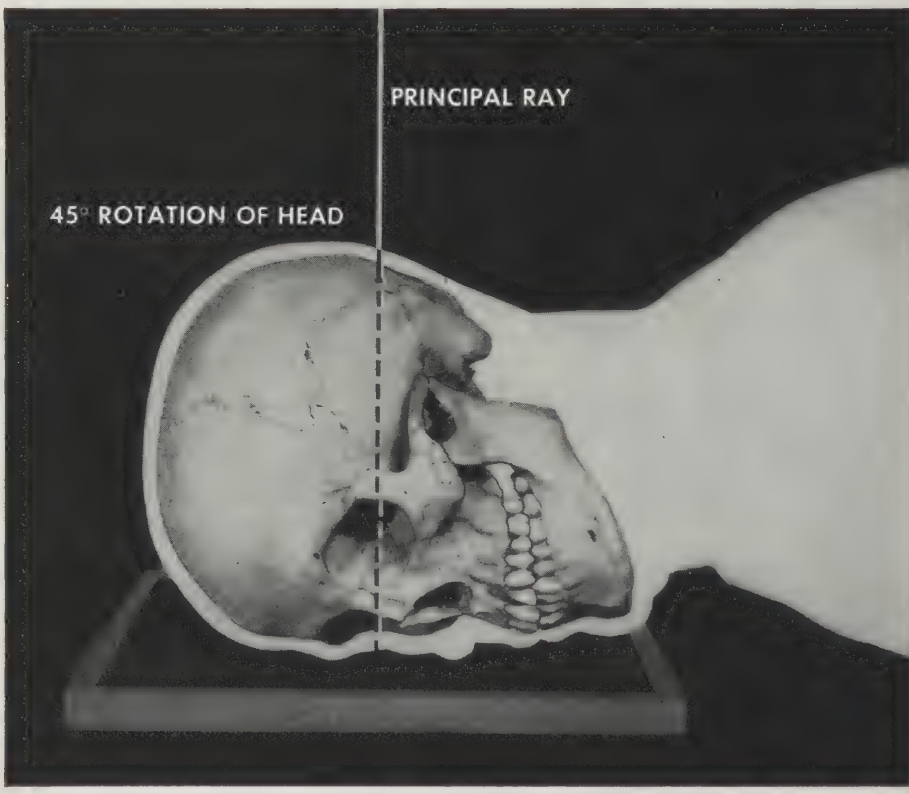
POSITION: Patient prone, arms flexed beneath chest; nose, forehead, cheek and chin in contact with cassette. Center of orbit to center of film.

FOCAL SPOT: Align to point 5 cm. above and 7 cm. posterior to external auditory meatus (i.e., that closer to tube), principal ray to emerge through center of orbit.

PRECAUTION: Suspended respiration, midsagittal plane 45° to cassette.

ADDITIONAL: Cone; grid optional.

VARIATIONS: Optic foramen better visualized by displacing tube laterally and angling 10° medially.

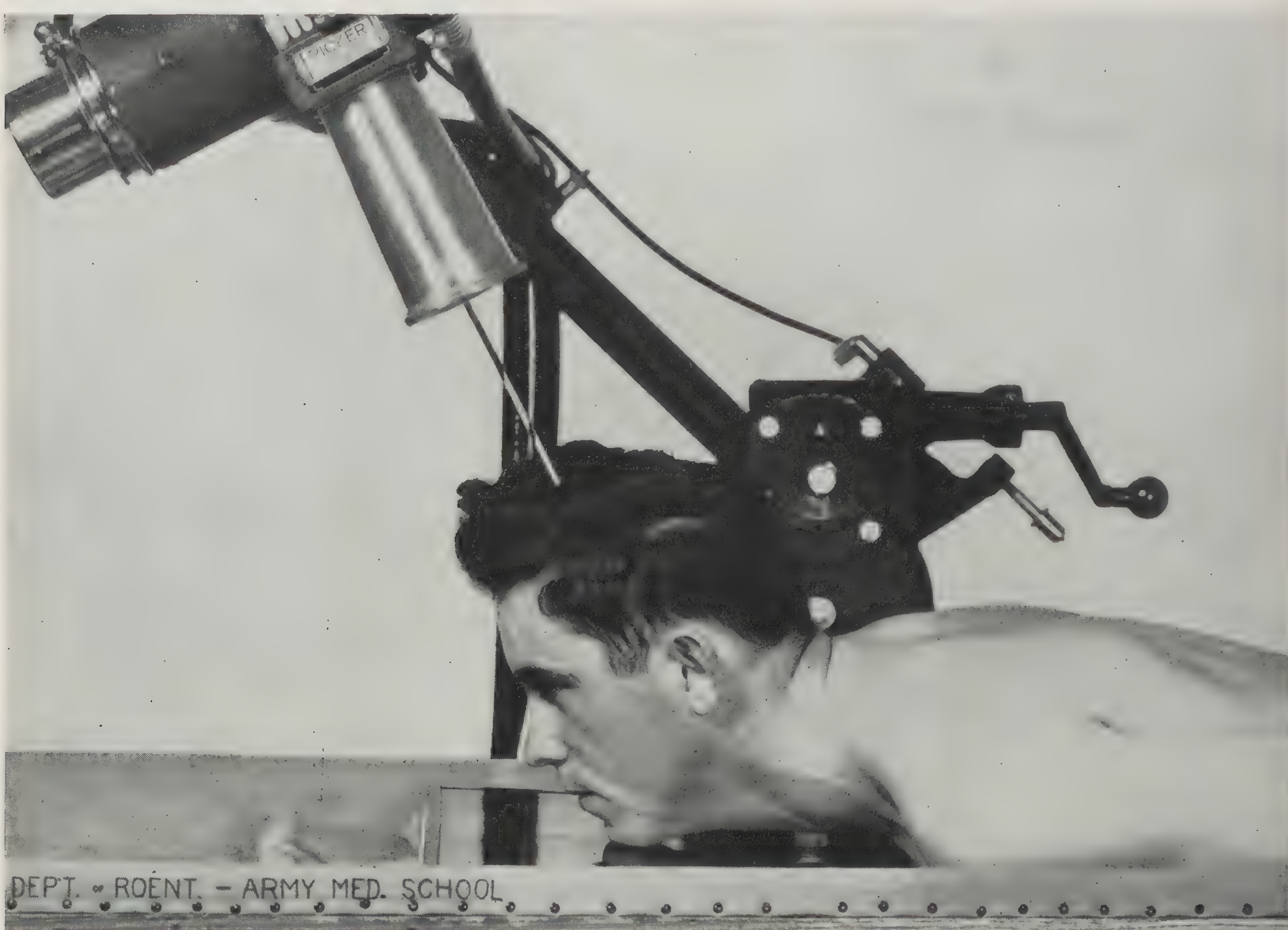


DISTANCE: 30″ — Measure plane through path of principal ray

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	64	66	68	70	72	74	76	78	70	72	74	76	78
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC		25								50				

AUXILIARIES: CONE.

Fig. 201.—PARANASAL SINUSES, SPHENOID—VERTICOSUBMENTAL



ANATOMICAL: Sphenoids and posterior ethmoid sinuses, temperomandibular articulation. Secondarily, structures at base of skull.

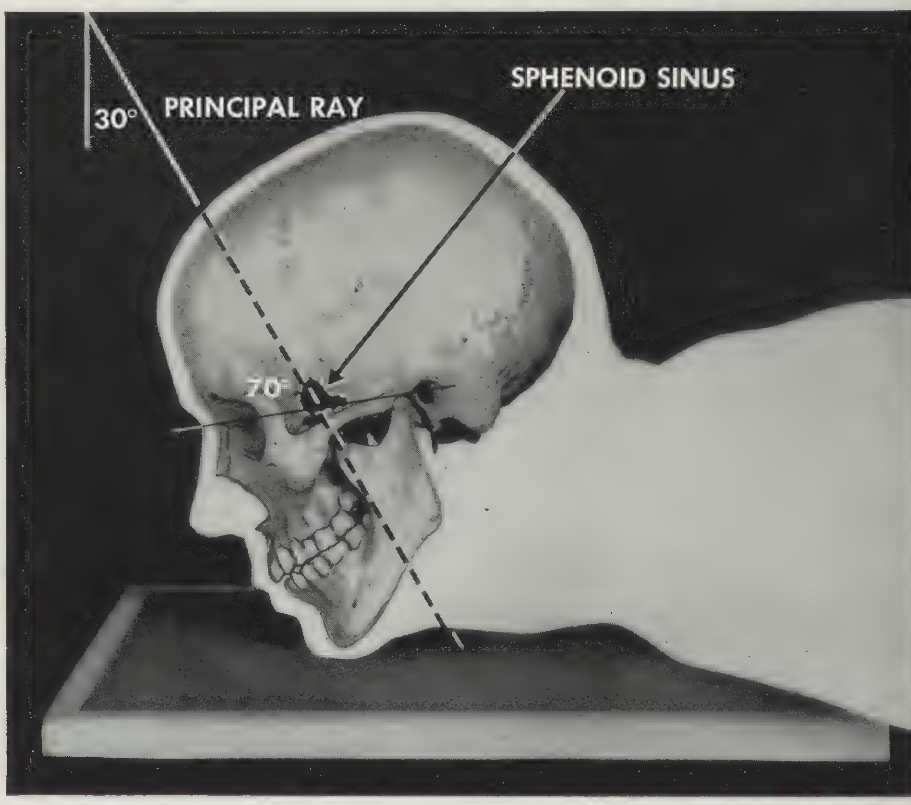
FILM: 10 x 12 inch, lengthwise.

POSITION: Patient prone, arms at sides, head in maximum extension, tip of chin 8 cm. above center of cassette. Midsagittal plane perpendicular to film through midwidth.

FOCAL SPOT: Align to vertex, principal ray 30° caudad, forming 70° angle with plane through canthi and auditory meati.

PRECAUTION: Plane through canthi and auditory meati as nearly parallel to film as possible. Suspended respiration.

ADDITIONAL: Grid optional. Cone advisable when sphenoid sinuses are especially considered.

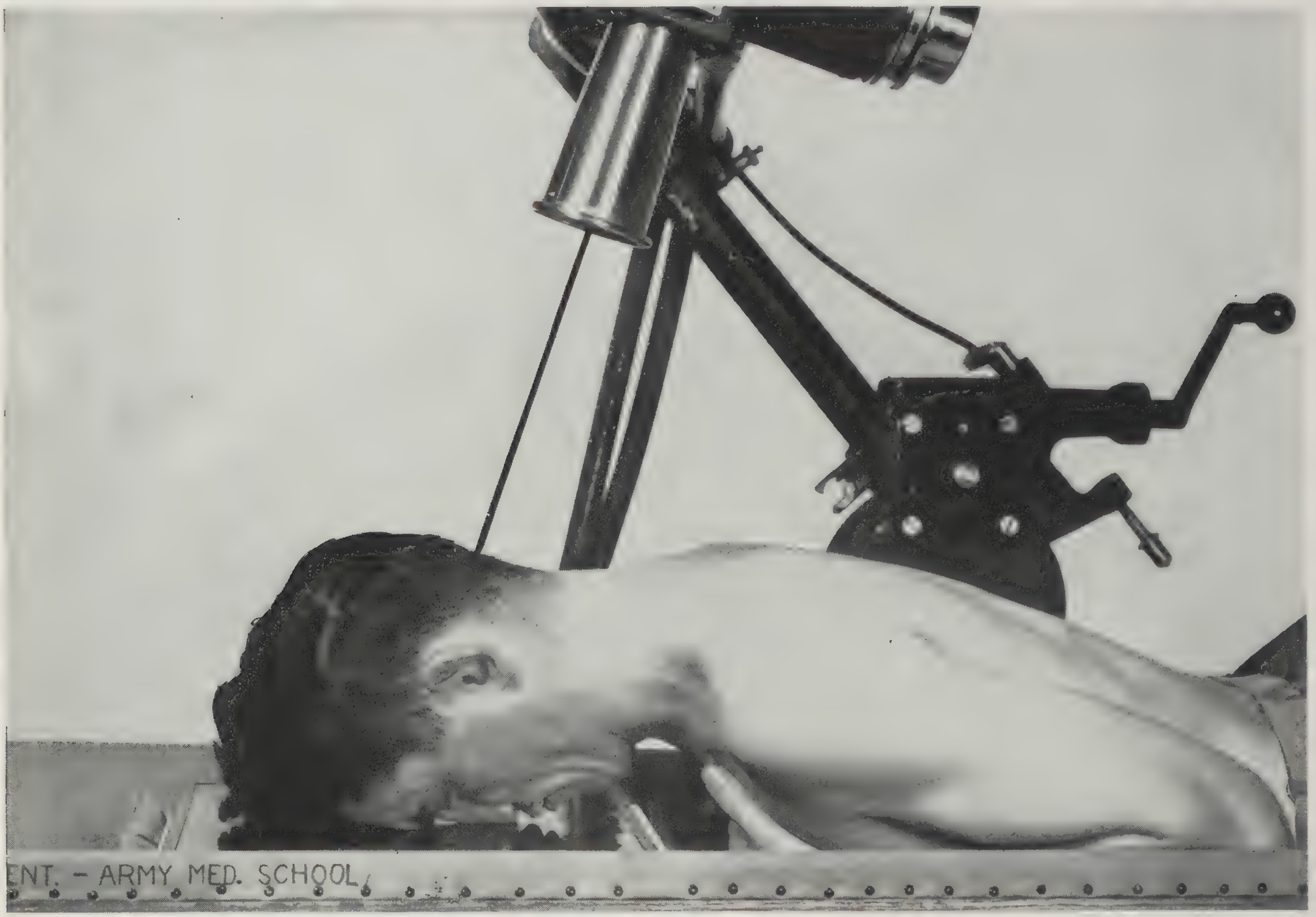


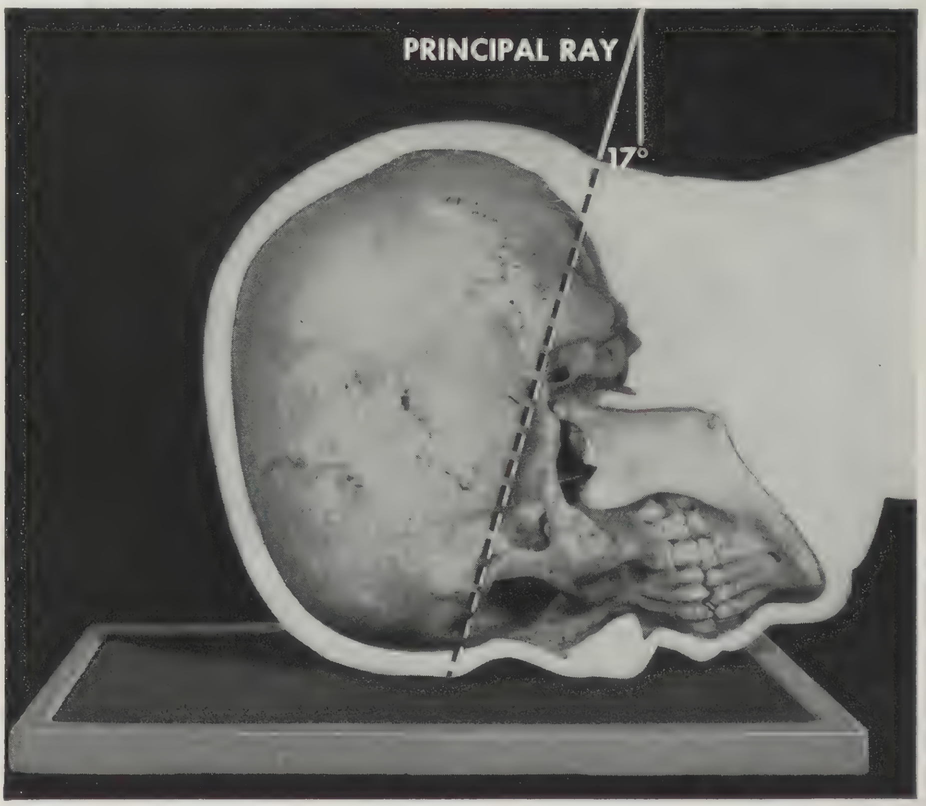
DISTANCE: 30″ — Measure along path of principal ray

CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	72	74	76	78	70	72	74	76	78	80	82	84
MA - SEC			75						150				

AUXILIARIES: **Cone** for 10 x 12″ coverage.

Fig. 202.—PARANASAL SINUSES, SUBOCCIPITOFRONTAL





ANATOMICAL: Frontals, roof of sphenoids and ethmoid sinuses.

FILM: 8 x 10 inch, lengthwise.

POSITION: Patient prone, forehead and nose in contact with film. Glabella at center of film.

FOCAL SPOT: Align to point 1 cm. below the external occipital protuberance, principal ray emerging through glabella, angled 17° cephalad.

PRECAUTION: Midsagittal plane perpendicular to and in midwidth of film. Suspended respiration. Remove dentures, etc.

ADDITIONAL: Cone; grid optional. Immobilization band, if available.

DISTANCE: 30″ Measure through plane of principal ray suboccipital to midfrontal bone through sphenoid area

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	64	66	63	70	72	74	76	78	80	72	74	76	78
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC						32						64		

AUXILIARIES: CONE.

Fig. 203.—SINUSES, MASTOID, LATERAL

ANATOMICAL: Mastoid antrum, sigmoid sinus, acoustic meati pyramid and temporomandibular articulation.

FILM: 8 x 10 inch, widthwise, one-half covered with lead mask.

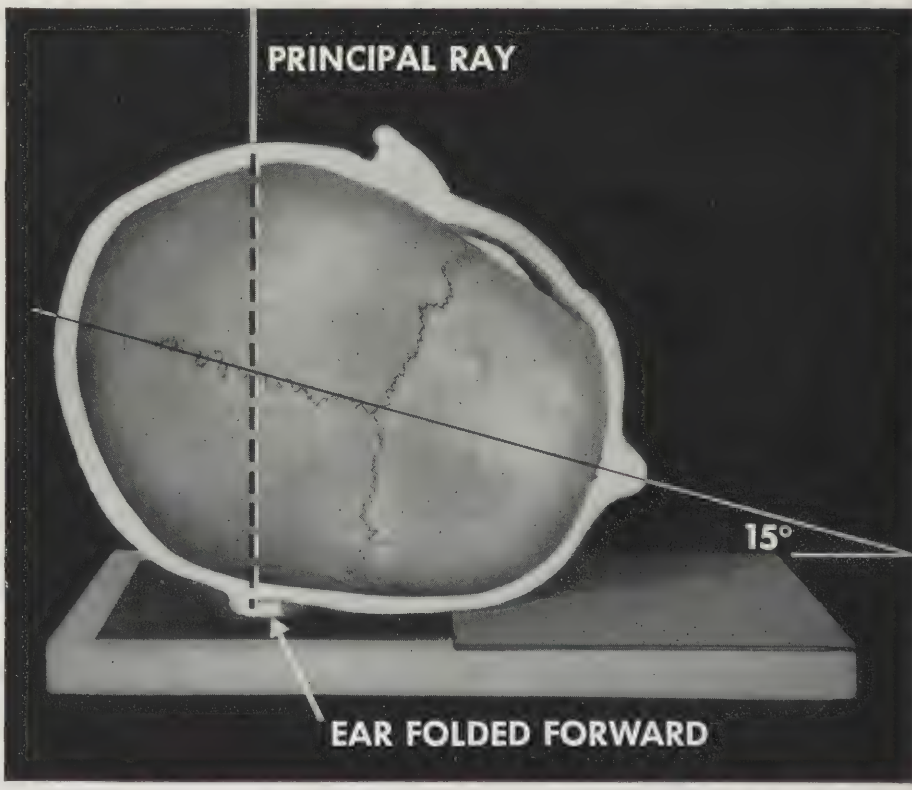
POSITION: Patient prone, forearm flexed beneath chest, external auditory meatus (of side for study) to center of one-half film. Head rotated 15° to film.

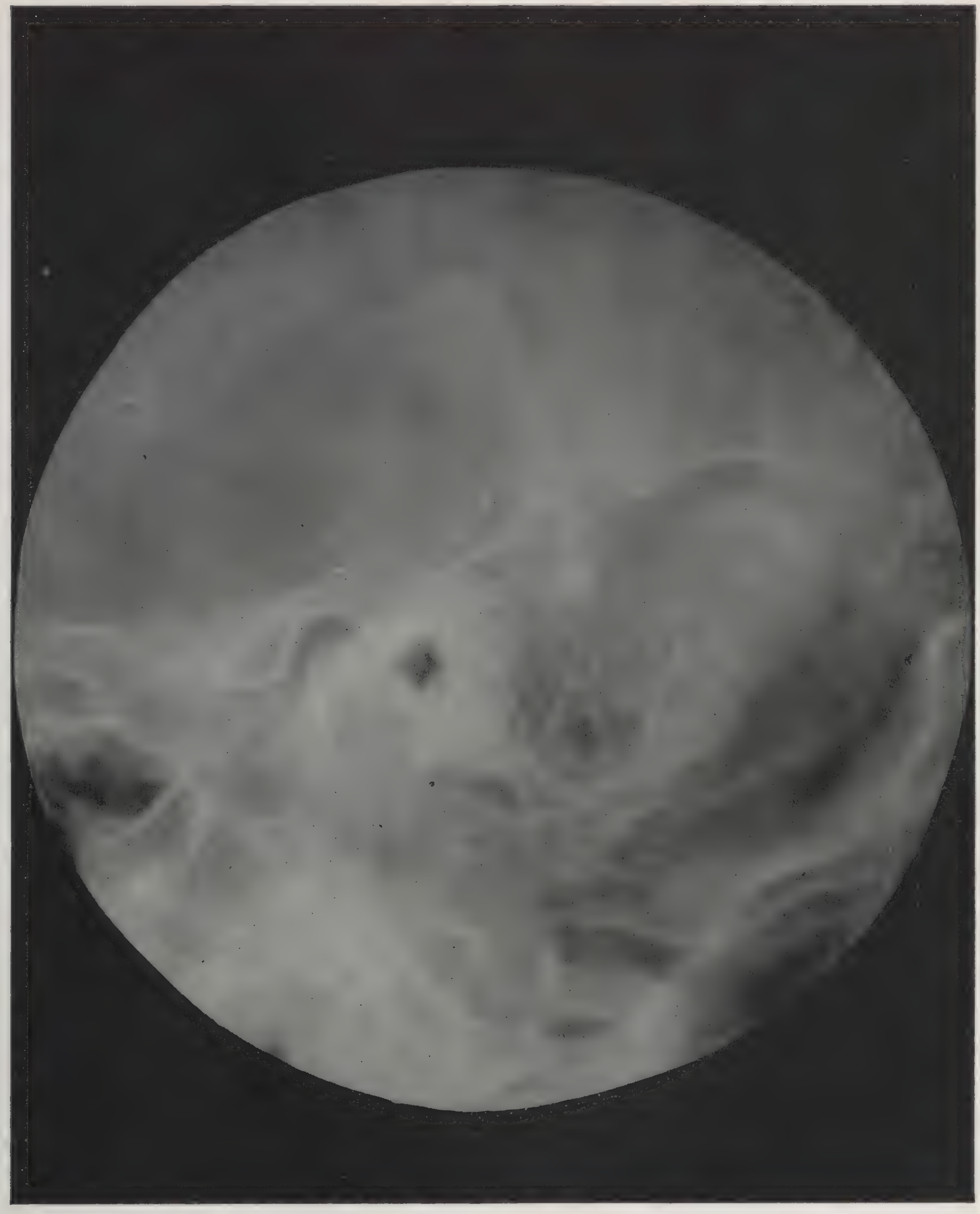
FOCAL SPOT: Align to point 5 cm. above and 5 cm. posterior to upper external auditory meatus, principal ray angled 15° toward feet.

PRECAUTION: Ear of affected side folded forward.

ADDITIONAL: Cone, fixation band.

VARIATION: To insure similar position of opposite side, measure distance from tip of nose to film and have equal for each side.

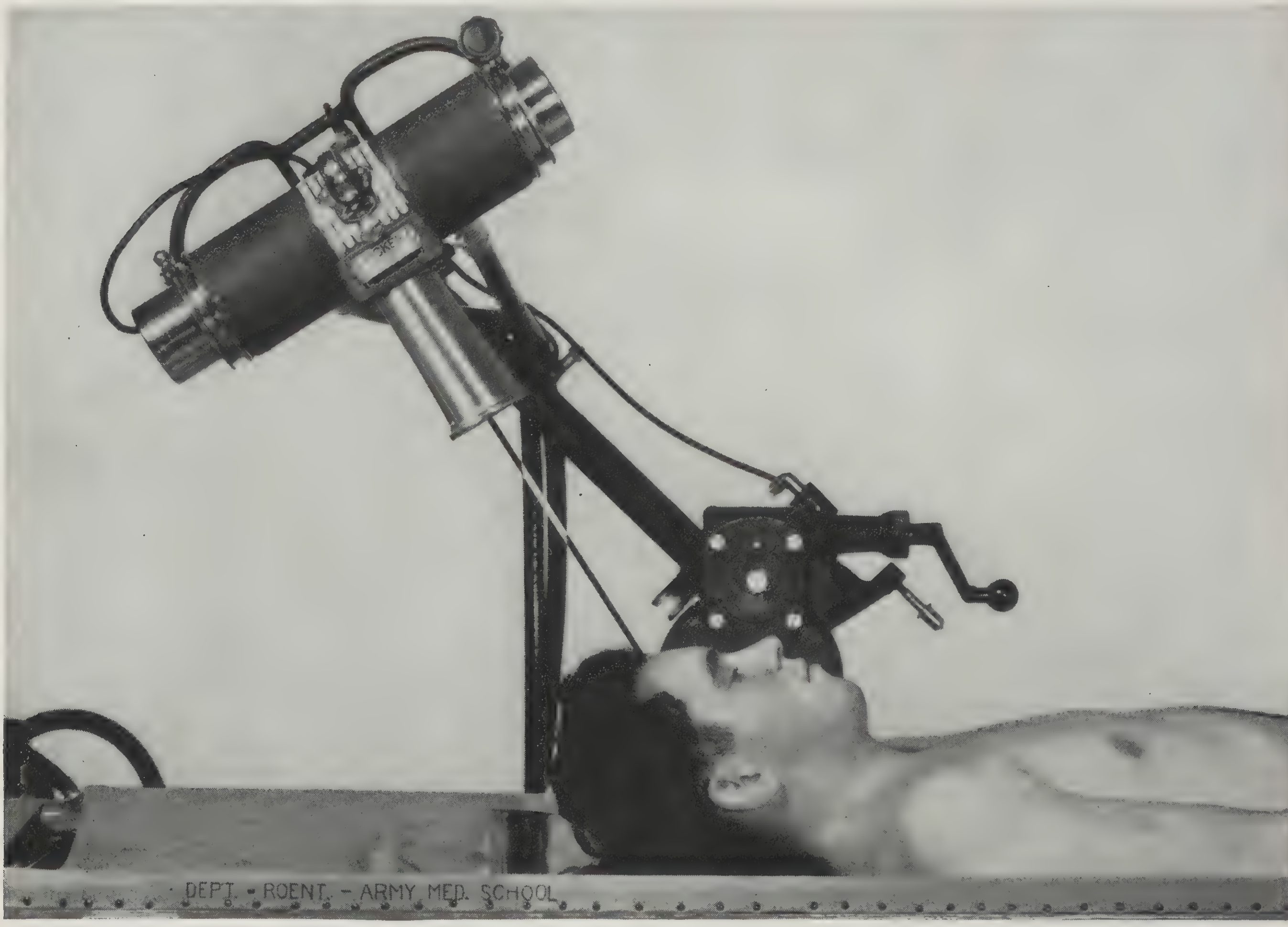


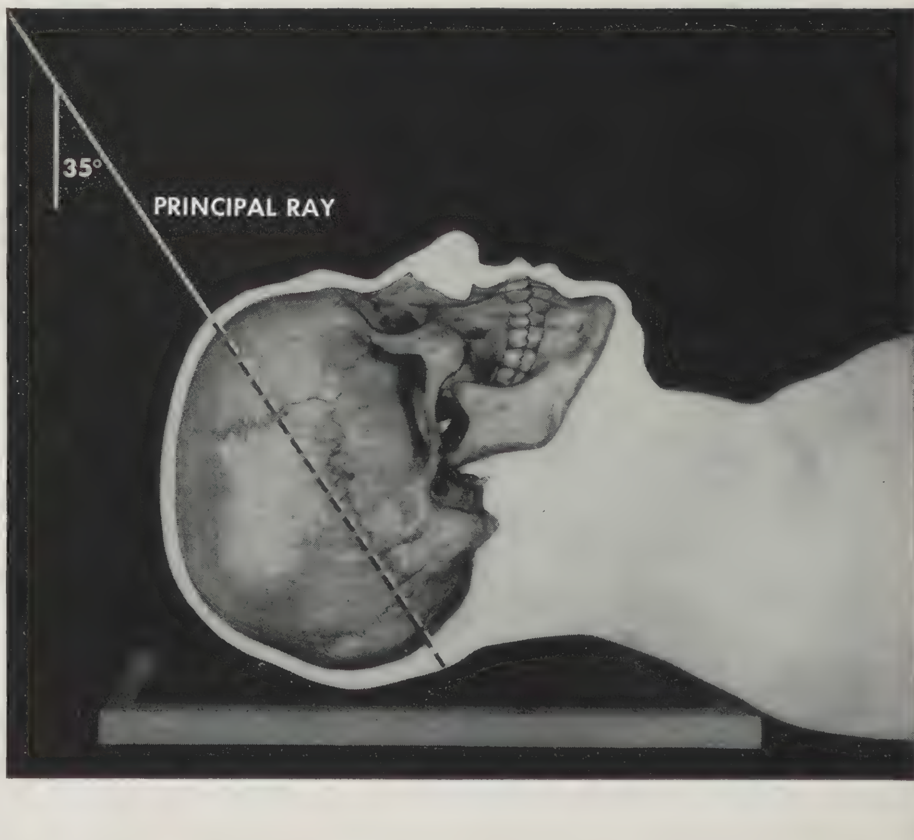


DISTANCE: 20″										Measure through path of principal ray
CMS. THICKNESS	11	12	13	14	15	16	17	18	19	20
VARIABLE KVP with cardboard holders	.	.	.	.	.	.	.	.	.	.
VARIABLE KVP with medium screens	70	72	74	76	78	70	72	74	76	78
VARIABLE KVP with Army wafer grid	.	.	.	.	.	.	.	.	.	.
MA - SEC.			11					22		

AUXILIARIES: CONE.

Fig. 204.—SINUSES, MASTOID FRONTO-OCCIPITAL





ANATOMICAL: Both mastoid processes, foramen magnum.

FILM: 8 x 10 inch, lengthwise.

POSITION: Patient supine, neck slightly flexed on chest; mastoid tips to midlength of film.

FOCAL SPOT: Align to midsagittal plane, principal ray directed at 35° angle caudad to emerge through plane of mastoid tips to center of film.

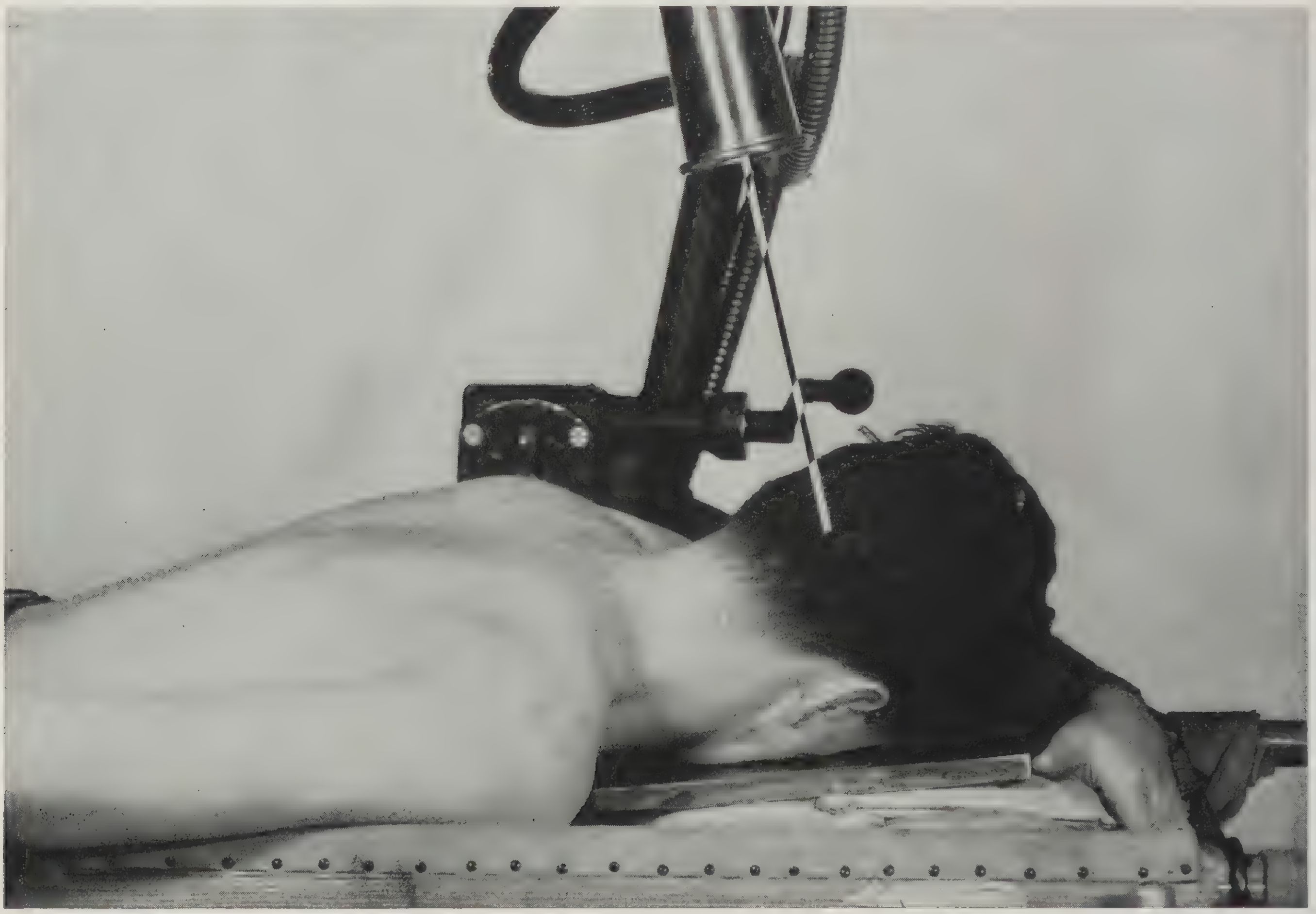
PRECAUTION: Midsagittal plane perpendicular to film; and in midwidth of film.

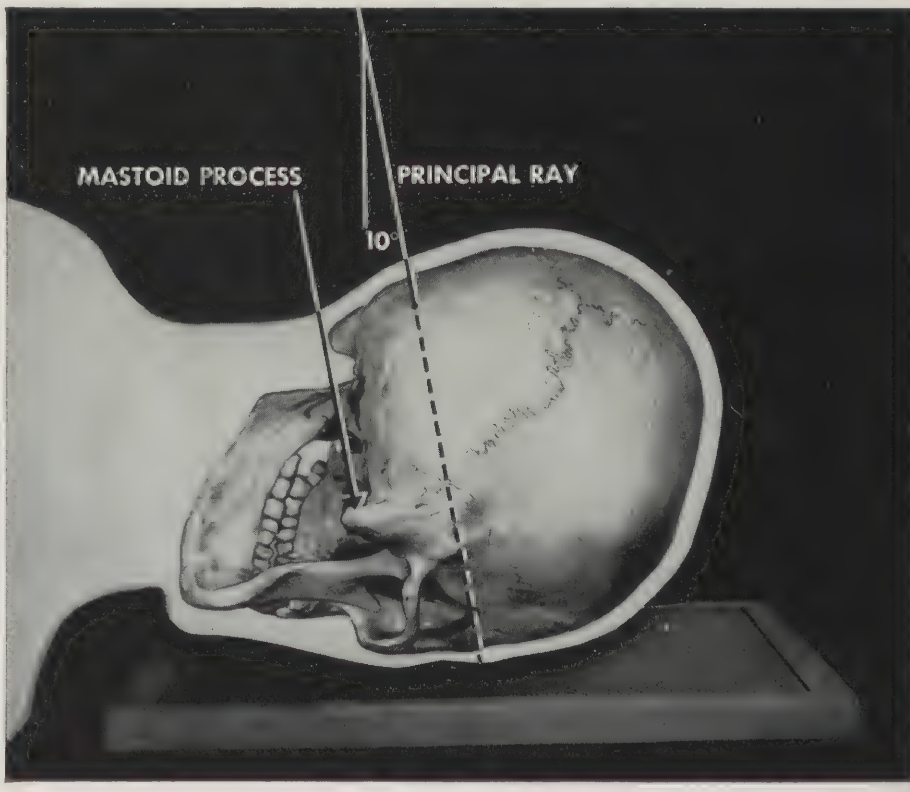
NOTE: This position is less satisfactory for detailed study of mastoid region, but is of value in examination of very ill patients.

<table>
<tr><td>DISTANCE: 30″</td><td colspan="13">Measure through oblique plane frontal hairline to occiput</td></tr>
<tr><td>CMS. THICKNESS</td><td></td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td></tr>
<tr><td rowspan="3">VARIABLE KVP</td><td>with cardboard holders</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>with medium screens</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>with Army wafer grid</td><td>70</td><td>72</td><td>74</td><td>76</td><td>78</td><td>80</td><td>82</td><td>84</td><td>76</td><td>78</td><td>80</td><td>82</td></tr>
<tr><td>MA - SEC</td><td></td><td colspan="8">64</td><td colspan="4">128</td></tr>
</table>

AUXILIARIES: CONE.

Fig. 205.—SINUSES, MASTOIDS, OCCIPITOTEMPORAL





ANATOMICAL: Mastoid antrum, petrous ridge, internal acoustic meatus. Secondarily, sigmoid sinus, temperomandibular articulation.

FILM: 8 x 10 inch, lengthwise, one-half covered with lead mask.

POSITION: Patient prone, forearm flexed beneath chest, head resting on nose, zygomatic prominence and forehead.

FOCAL SPOT: Align principal ray to external occipital protuberance with tube angled 10° cephalad to center of film.

PRECAUTION: Midsagittal plane 45° angle to film.

ADDITIONAL: Cone, grid. Immobilization.

NOTE: Recommend similar projection of opposite side.

DISTANCE: 30″	Measure plane through mastoid process and supra-orbital ridge, obliquely									
CMS. THICKNESS		14	15	16	17	18	19	20	21	22
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.
	with medium screens	70	72	74	76	78	70	72	74	76
	with Army wafer grid	.	.	.	.	.	.	.	.	.
MA - SEC.				8				16		

AUXILIARIES: CONE.

Fig. 206.—SINUSES, MASTOID, TEMPERO-OCCIPITAL

ANATOMICAL: Petrous ridge, mastoid antrum and tip.

FILM: 8 x 10 inch, widthwise; one-half covered with lead mask.

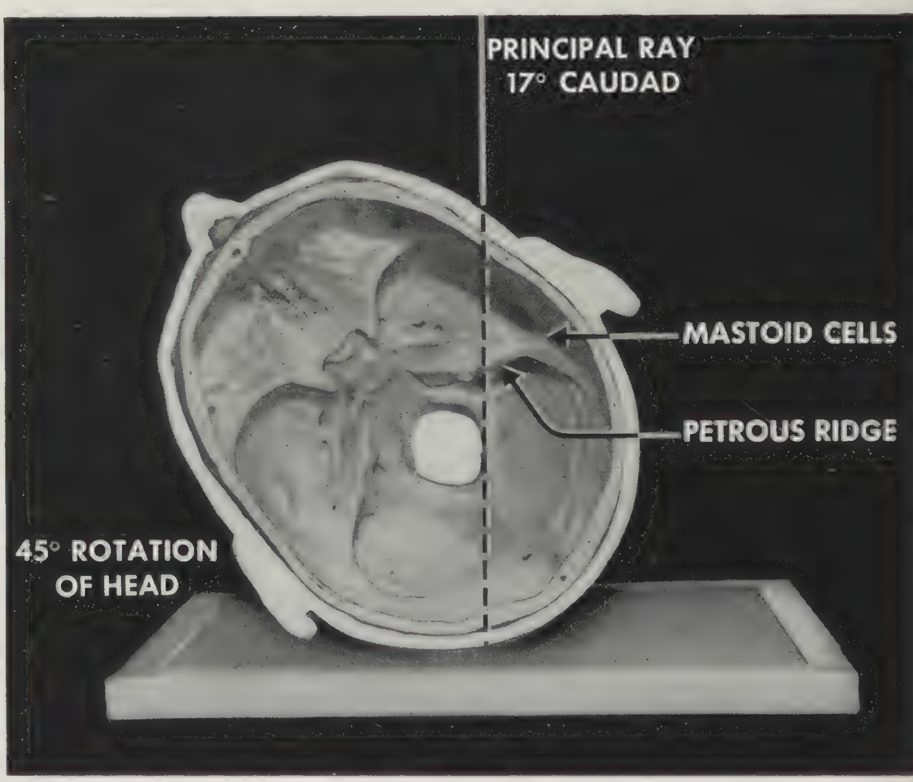
POSITION: Patient supine, midsagittal plane of head rotated 45 to 50°, side under study up from film.

FOCAL SPOT: Align to point midway between external canthus and external auditory meatus; principal ray directed 17° caudally.

PRECAUTION: Chin slightly depressed.

ADDITIONAL: Cone recommended; grid optional.

NOTE: Recommend similar projection of opposite side accomplished with patient prone.



DISTANCE: 30″ Measure plane through mastoid process and supra-orbital ridge, obliquely

CMS. THICKNESS		14	15	16	17	18	19	20	21	22
VARIABLE KVP	with cardboard holders									
	with medium screens	70	72	74	76	78	70	72	74	76
	with Army wafer grid									
MA - SEC.				8				16		

AUXILIARIES: CONE.

Fig. 207.—SINUSES, MASTOID, ANTEROPOSTERIOR

ANATOMICAL: Mastoid tip, petrous ridge.

FILM: 8 x 10 inch, widthwise, one-half covered with lead mask.

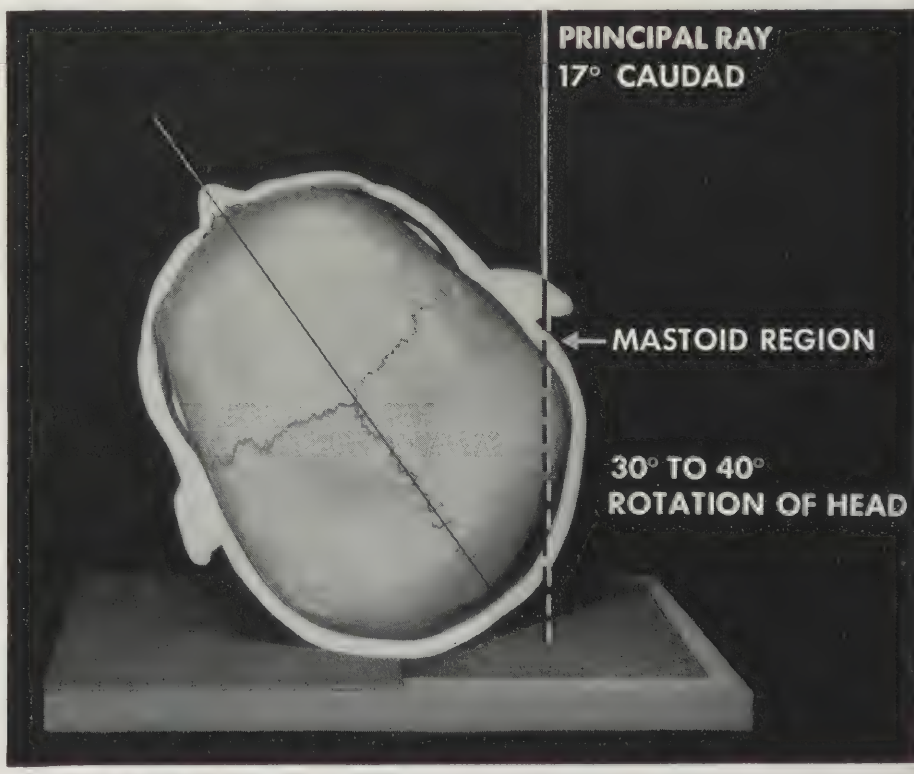
POSITION: Patient supine, head rotated 30 to 40°; side under study up from film, mastoid tip to center of exposed half of film.

FOCAL SPOT: Align to point 1 cm. above external auditory meatus, principal ray passing through base of mastoid process. Angle tube so as to direct principal ray 17° caudad.

PRECAUTION: Rotation should be sufficient to remove mastoid tip from behind angle of mandible.

ADDITIONAL: Cone; grid may be used.

NOTE: Recommend similar projection of opposite side.

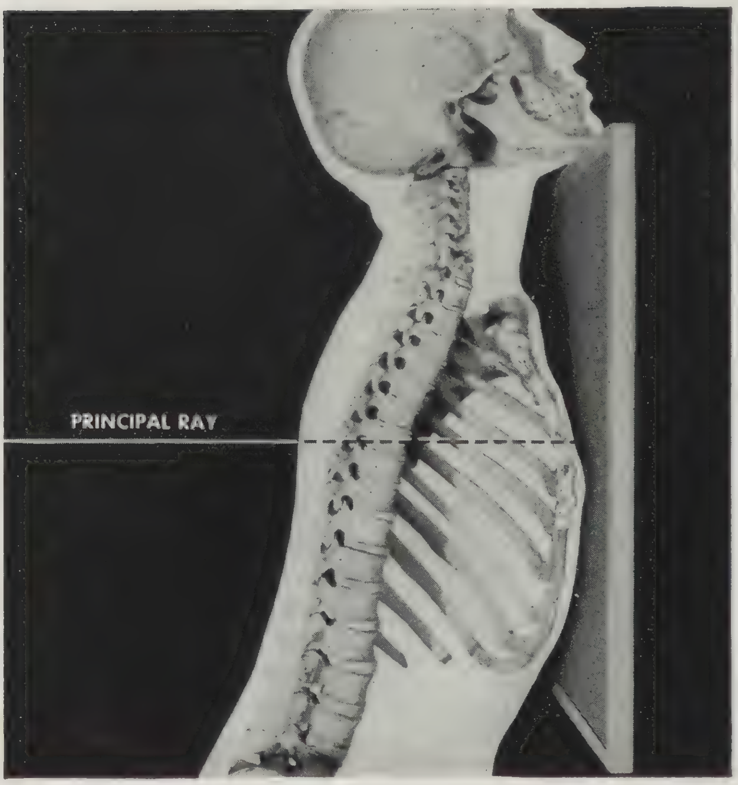


DISTANCE: 30″ Measure plane through supra-orbital ridge and mastoid process, obliquely

CMS. THICKNESS		13	14	15	16	17	18	19	20
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.
	with medium screens	50	52	54	56	58	60	62	64
	with Army wafer grid	.	.	.	.	.	.	.	.
MA - SEC.		22							

AUXILIARIES: CONE.

Fig. 208.—CHEST, POSTERO-ANTERIOR (erect)



ANATOMICAL: Lungs, heart, aorta; secondarily, ribs, thoracic spine and soft tissues.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient erect leaning forward at an angle of 5°; chin resting on upper border of cassette; neck stretched, with plane of acromial processes 5 to 7 cm. below upper border of film; midsagittal plane to midwidth of film and perpendicular to it; dorsum of hand on hips with shoulders rotated forward.

FOCAL SPOT: Align to center of film.

PRECAUTION: Respiration suspended in normal full inspiration.

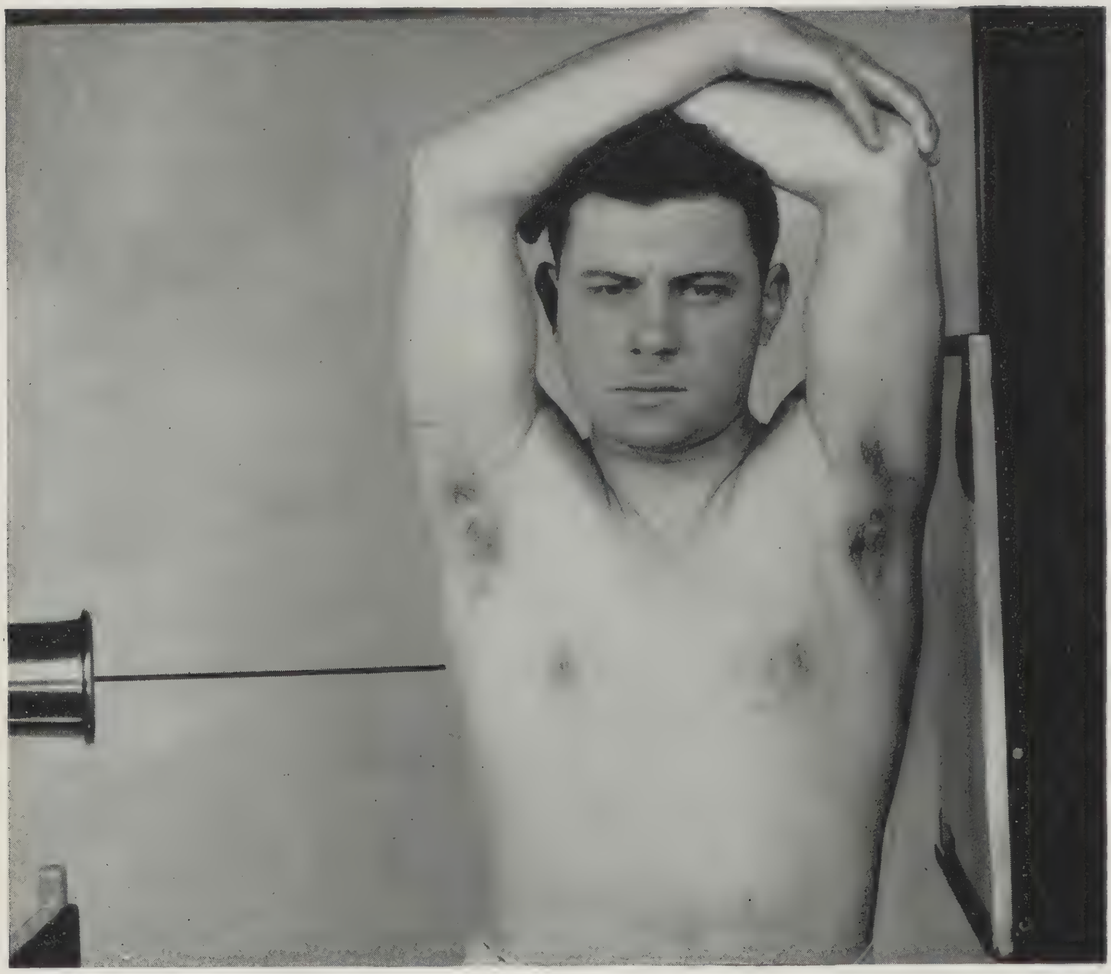
ADDITIONAL: Vertical cassette holder advisable.

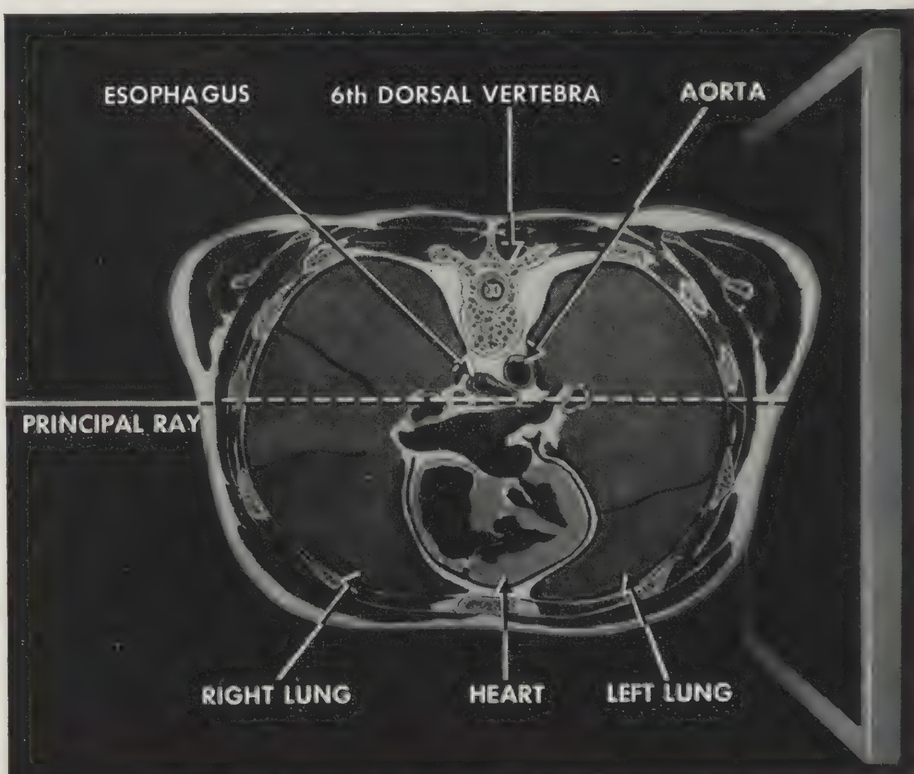
NOTE: For cardiac study, center to 9th thoracic vertebra.

DISTANCE: 60″ — Measure through plane at level of lower border of manubrium

CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	74	76	78	80	82	84	76	78	80	82	84	80	82	84	80	82	84
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC				4						8				12			16	

Fig. 209.—CHEST, LATERAL (erect)



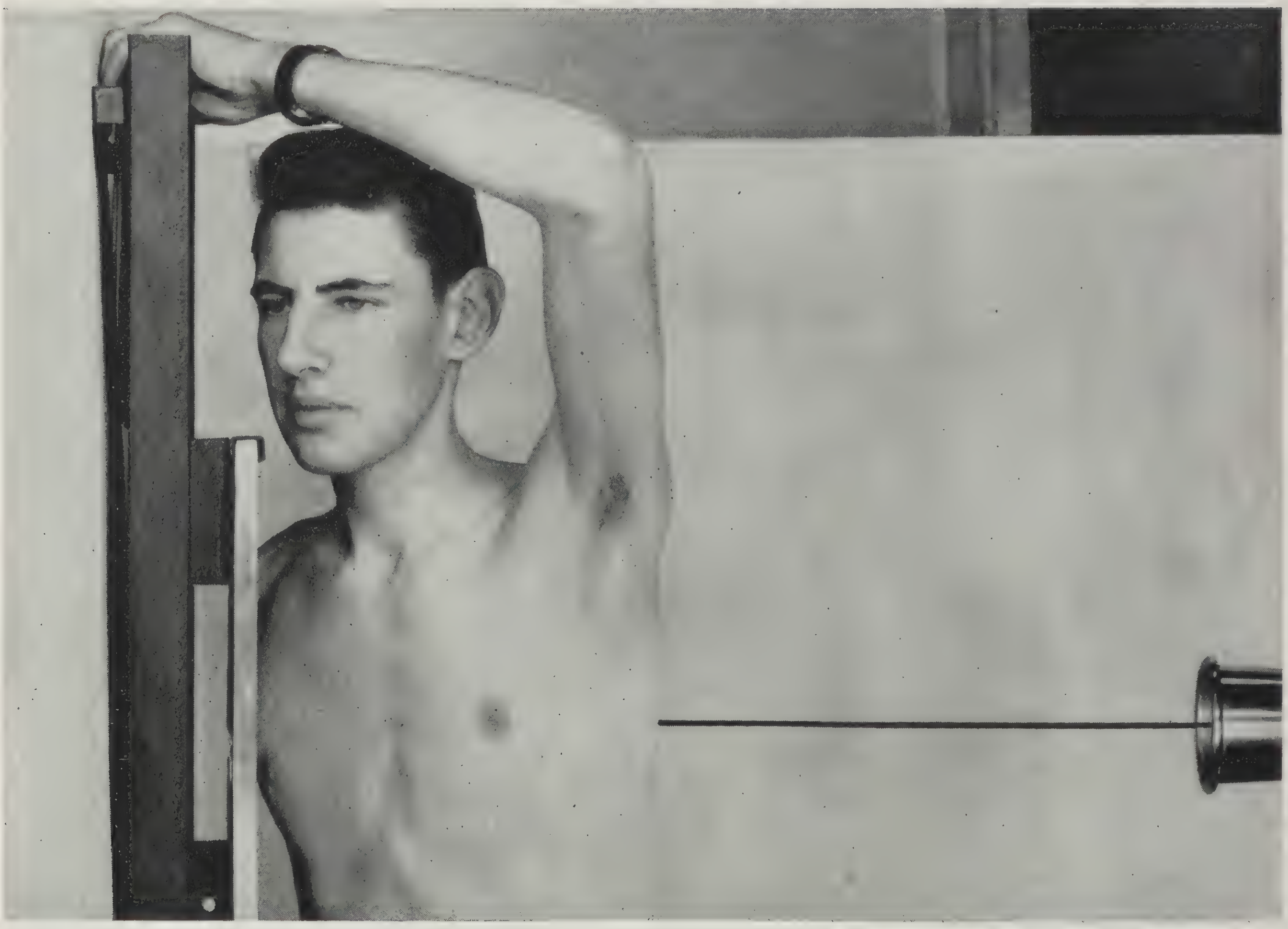


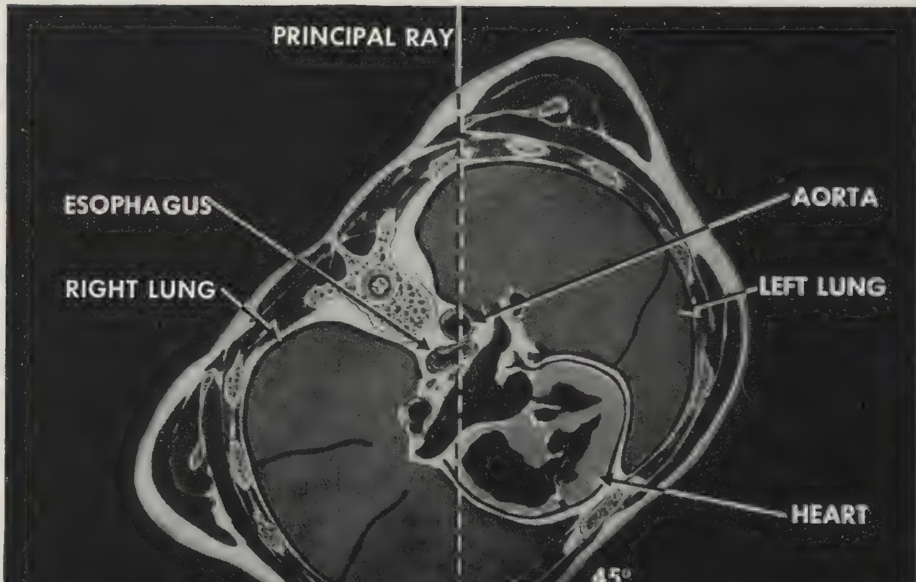
ANATOMICAL: As previously described; in particular interlobar fissures; anterior and superior mediastinum.
FILM: 14 x 17 inch, lengthwise, vertical.
POSITION: Patient erect, lateral chest wall of side under study in contact with cassette; plane of acromial processes 7 to 9 cm. below upper border of cassette; arms folded above head. Mid-axillary plane to midwidth of film.
FOCAL SPOT: Align to center of film.
PRECAUTION: Respiration suspended in normal full inspiration.
ADDITIONAL: Stationary cassette holder advisable.
VARIATIONS: Greater focal-film distance recommended (change technical factors in accordance with inverse square law).

DISTANCE: 60″ Measure through plane at level of lower border of manubrium

CMS. THICKNESS		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	70	72	74	76	78	80	72	74	76	78	80	82	84	76	78	80	82
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC					14						28					54		

Fig. 210.—CHEST, RIGHT ANTERIOR OBLIQUE (erect)





ANATOMICAL: As previously described; in particular posterior portion of right costophrenic sulcus.

FILM: 14 x 17 inch, lengthwise, vertical.

POSITION: Patient erect, chest rotated 45 to 55° right side in contact with film; right acromial process 7 to 9 cm. below upper border of cassette.

FOCAL SPOT: Align to center of film.

PRECAUTION: Respiration suspended in normal full inspiration.

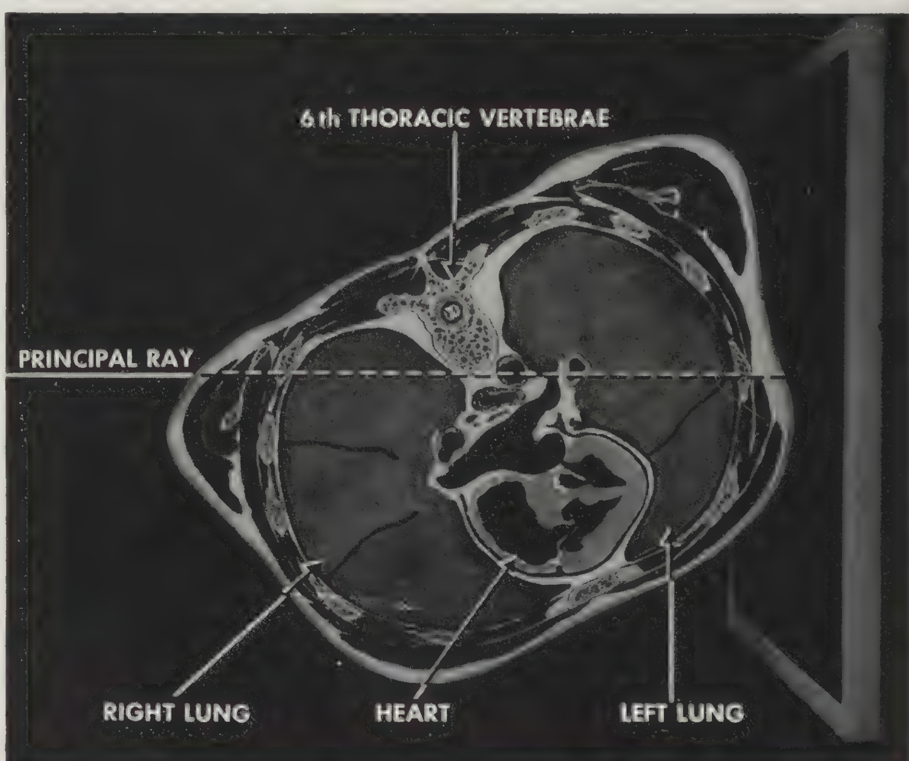
ADDITIONAL: Stationary cassette holder advisable.

VARIATIONS: Greater focal-film distance recommended (change technical factors in accordance with inverse square law).

DISTANCE: 60″ — Measure through plane of principal ray

CMS. THICKNESS		18	19	20	21	22	23	24	25	26	27	28	29	39	31	32	33	34
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	64	66	68	70	72	74	76	78	70	72	74	76	78	70	72	74	76
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC		15.								30					60			

Fig. 211.—CHEST, LEFT ANTERIOR OBLIQUE (erect)

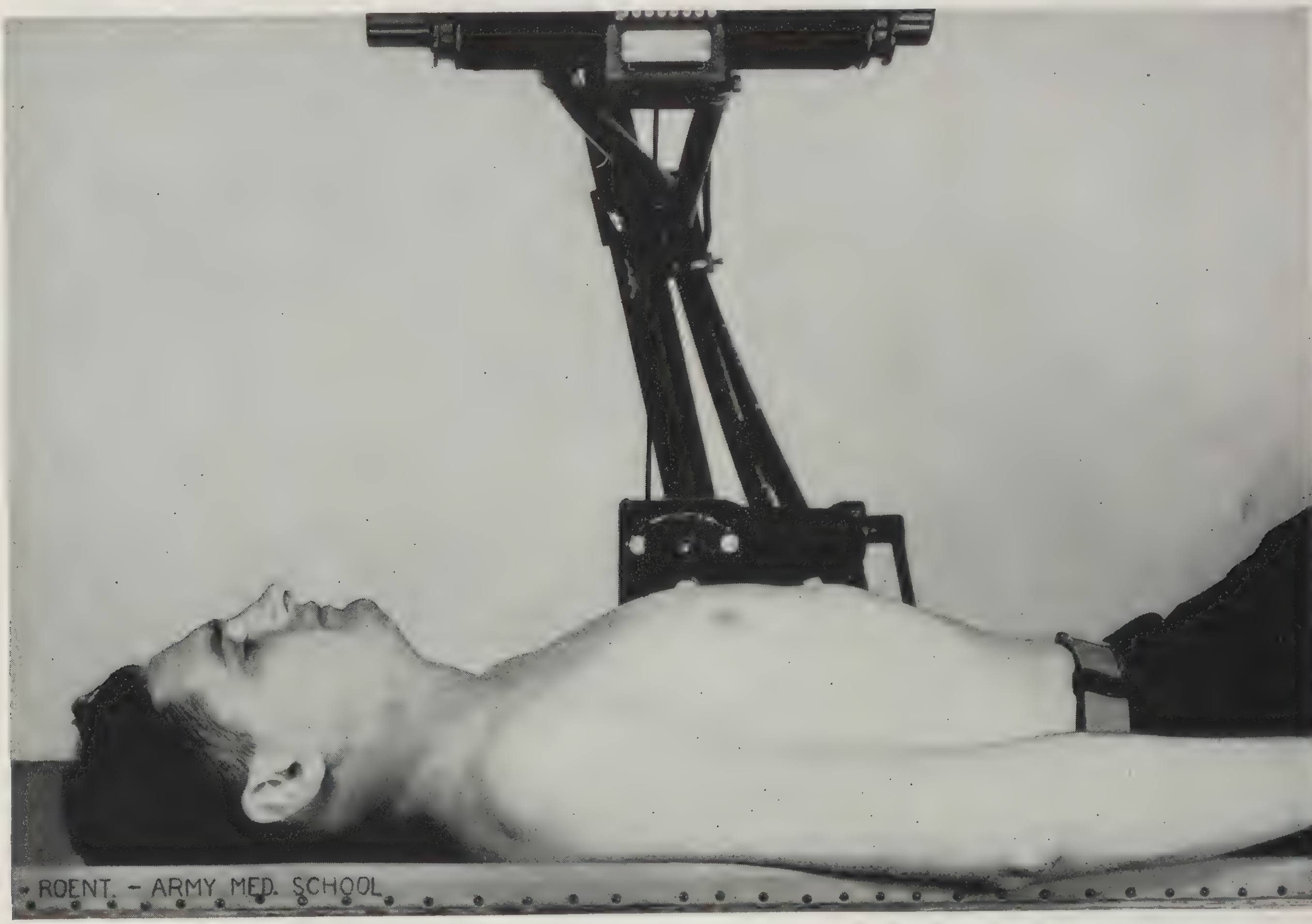


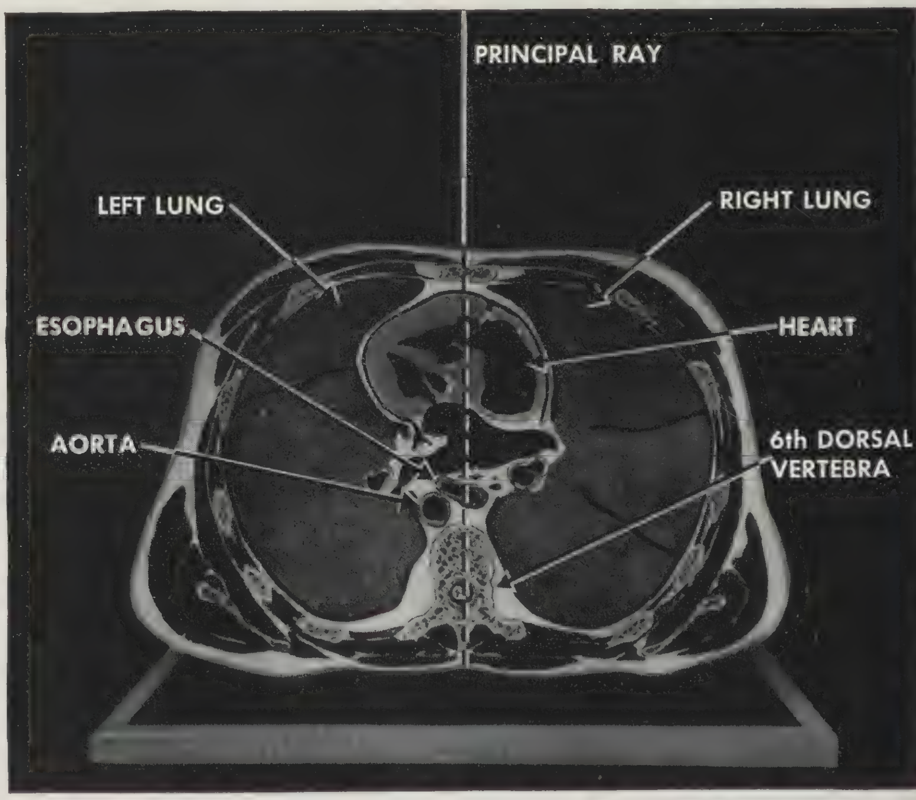
ANATOMICAL: As previously described; in particular, arch of aorta, right lung field, posterior portion of left costophrenic sulcus.
FILM: 14 x 17 inch, lengthwise, vertical.
POSITION: Patient erect; chest rotated 55 to 70° with left chest and shoulder in contact with film; left acromial process 7 to 9 cm. below upper border of cassette.
FOCAL SPOT: Align to center of film.
PRECAUTION: Respiration suspended in normal full inspiration. Principal ray perpendicular to film.
ADDITIONAL: Stationary cassette holder advisable.
VARIATIONS: Greater focal-film distance easily accommodated by changing technical factors in accordance with inverse square law.

DISTANCE: 60″ — Measure through plane of principal ray

CMS. THICKNESS		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	64	66	68	70	72	74	76	78	70	72	74	76	78	72	74	76	78
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC					24							48				96		

Fig. 212.—CHEST, ANTEROPOSTERIOR (bedside)





ANATOMICAL: As previously described.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient supine, arms at sides; plane of acromial processes 5 to 7 cm. below upper border of film.

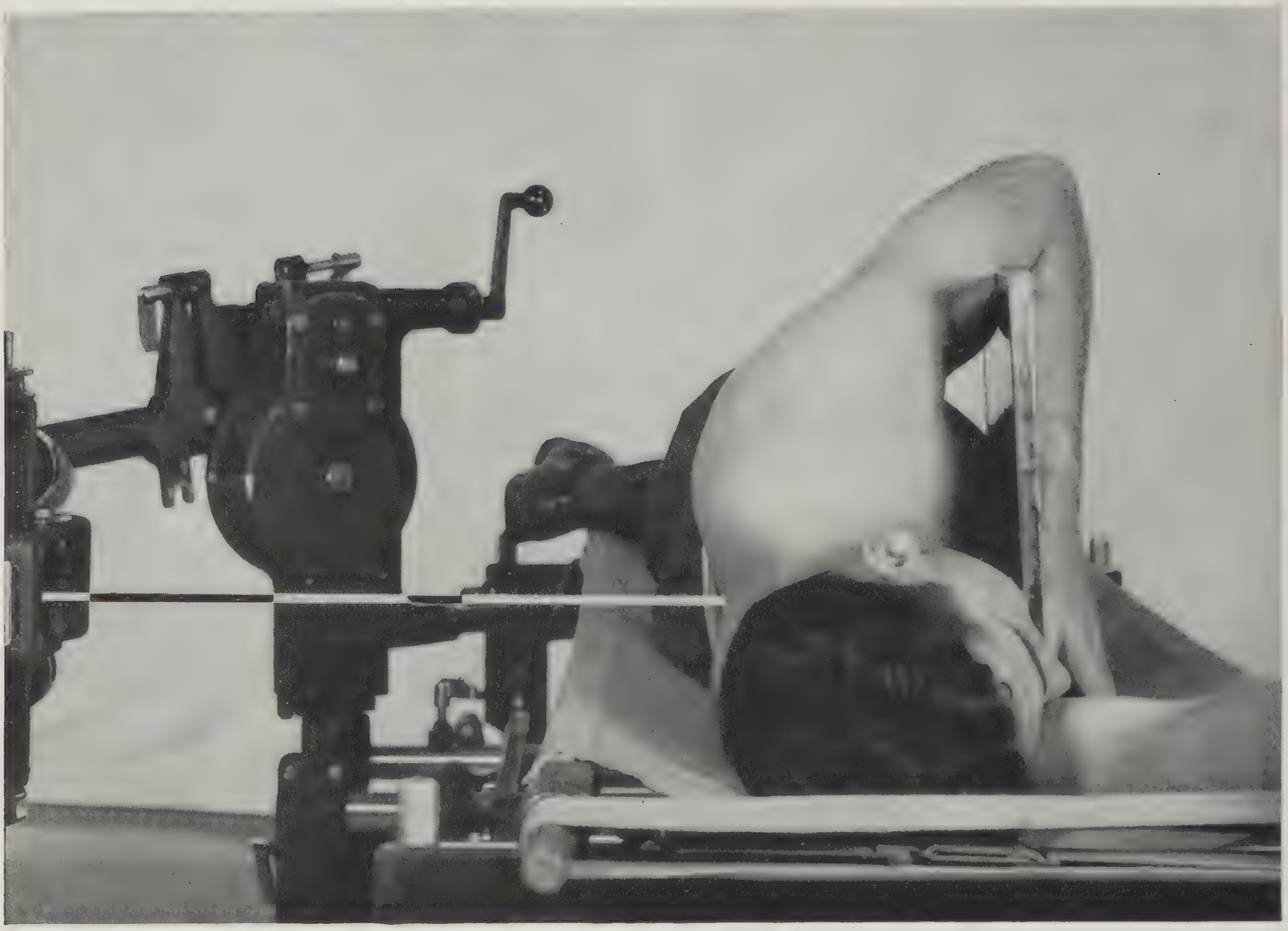
FOCAL SPOT: Align to center of film.

PRECAUTION: Respiration suspended in normal full inspiration; depress shoulders.

DISTANCE: 30″ Measure through plane lower border of manubrium

CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
VARIABLE KVP	with cardboard holders																
	with medium screens	54	56	58	60	62	64	66	68	70	72	74	66	68	70	72	74
	with Army wafer grid																
MA - SEC		4											8				

Fig. 213.—CHEST, POSTERO-ANTERIOR, (lateral recumbent)



ANATOMICAL: Lung of upper side, pleura, etc.

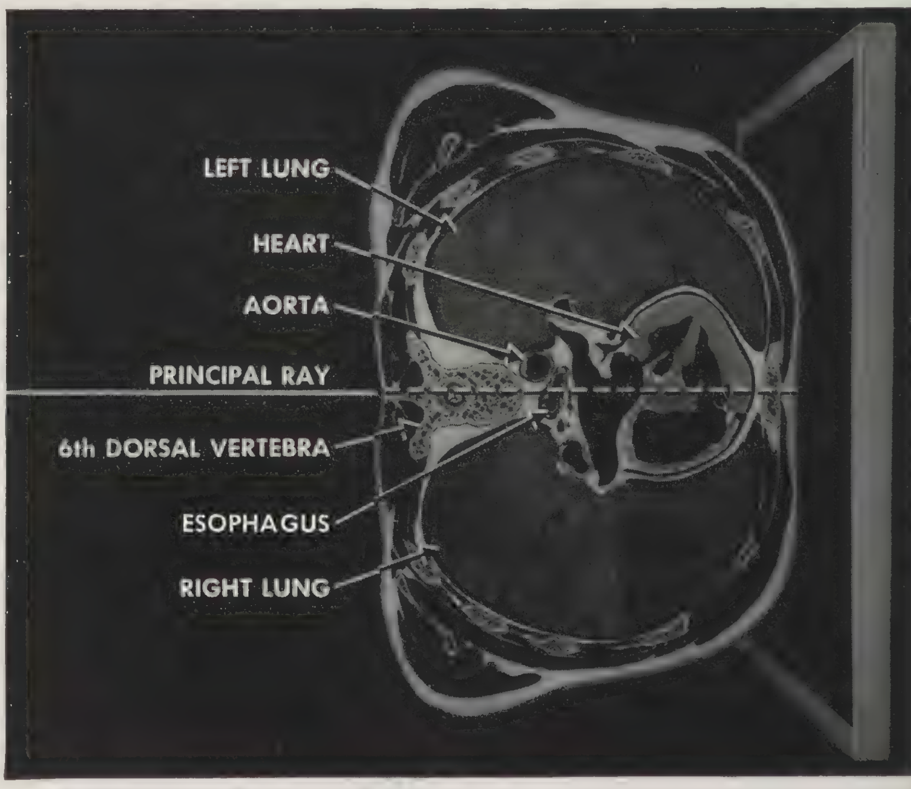
FILM: 14 x 17 inch, vertical.

POSITION: Patient laterally recumbent, holding cassette against front of chest; plane of acromial processes 5 to 7 cm. below upper border of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Respiration suspended in normal full inspiration. Head supported to keep thoracic vertebrae in horizontal plane; dependent side of chest supported and raised by pillows to include full width of thorax on film.

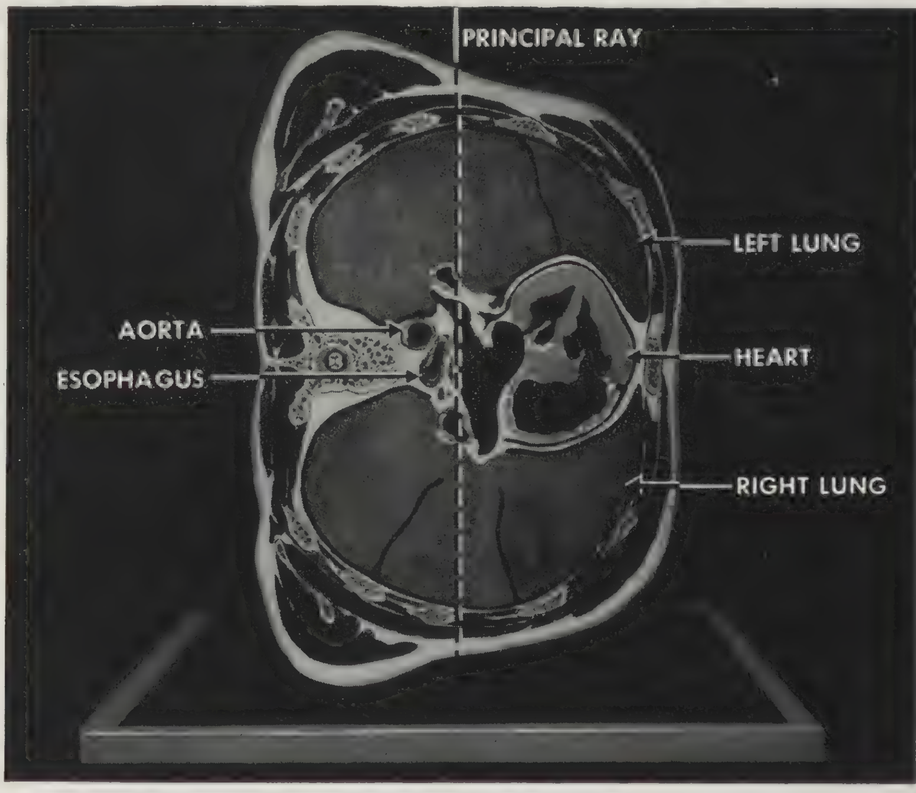
NOTE: Valuable for demonstration of pleural fluid and fluid levels, with the affected side elevated or depressed, depending on individual indications.



DISTANCE: 30″ — Measure through plane of lower border of manubrium

		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
CMS. THICKNESS		**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	**54**	**56**	**58**	**60**	**62**	**64**	**66**	**68**	**70**	**72**	**74**	**66**	**68**	**70**	**72**	**74**
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC							**4**								**8**		

Fig. 214.—CHEST, LATERAL (recumbent)



ANATOMICAL: As previously described.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient laterally recumbent, midaxillary plane to midwidth of film; plane of acromial processes 5 to 7 cm. below upper border of film. Arms extended over head.

FOCAL SPOT: Align to center of film.

PRECAUTION: Suspended respiration in normal full inspiration.

NOTE: Lateral chest examination in very ill is performed by placing cassette vertically against one side of supine patient and directing ray from opposite side.

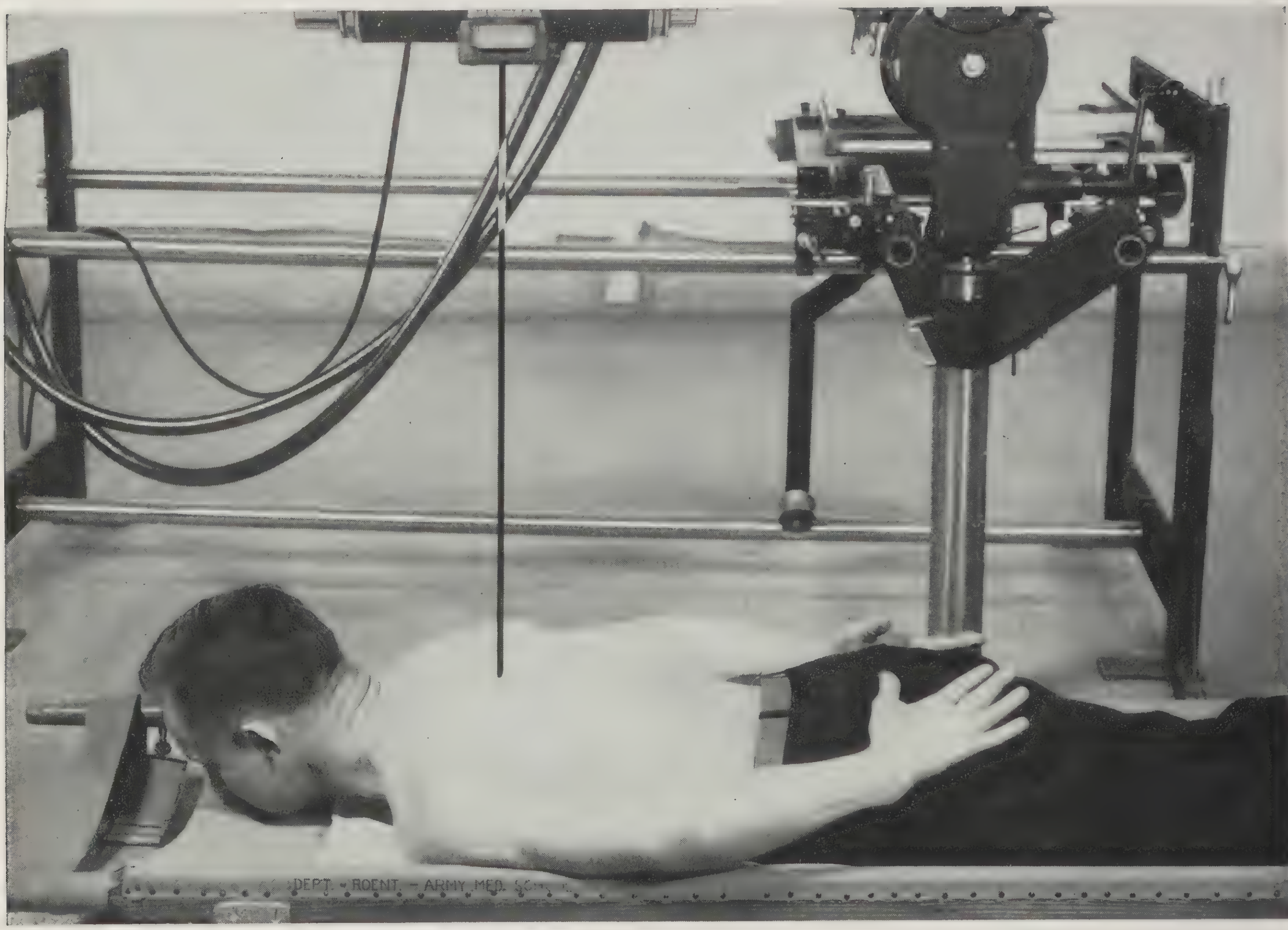
DISTANCE: 30″

Measure through plane, midlevel of sternum, laterally

CMS. THICKNESS		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	62	64	66	68	70	72	74	76	78	70	72	74	76	78	80	82	84
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

MA - SEC . . . . 30 (thicknesses 18–26) . . . . 60 (thicknesses 27–34)

Fig. 215.—CHEST, POSTERO-ANTERIOR (recumbent)



ANATOMICAL: As previously described; in particular, heart, great vessels, lungs, diaphragm, thoracic cage.

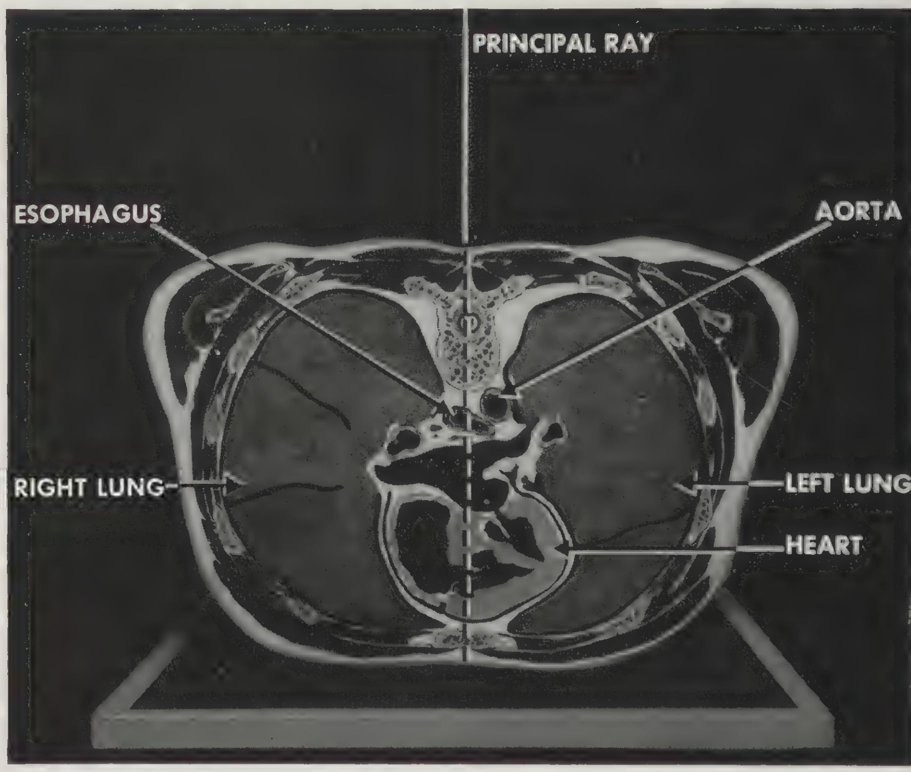
FILM: 14 x 17 inch, lengthwise.

POSITION: Patient prone, shoulders forward, arms at side with backs of hands on hips. Plane of acromial processes 5 to 7 cm. below upper border of film.

FOCAL SPOT: Align to center of film.

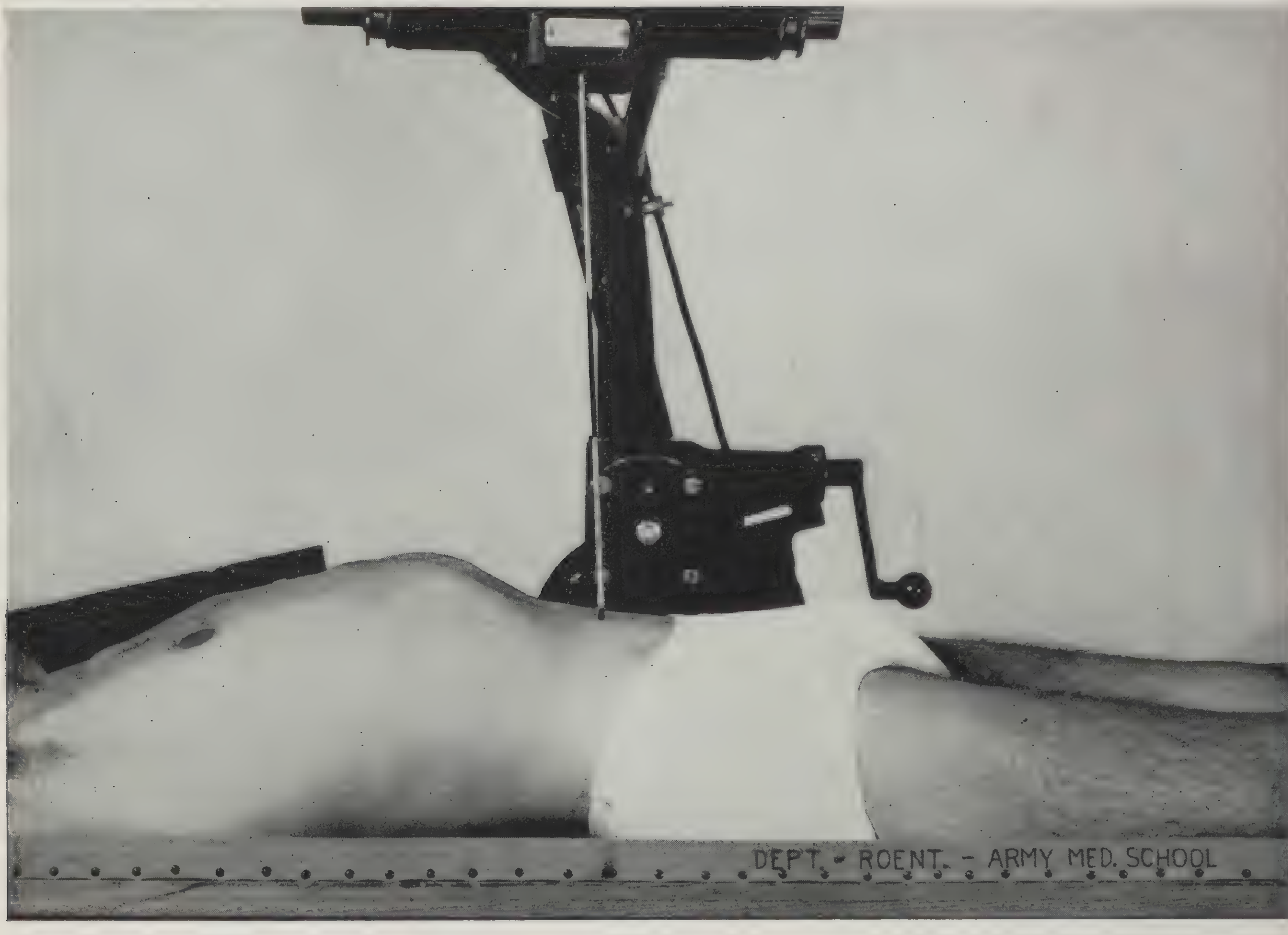
PRECAUTION: Respiration suspended in normal full inspiration.

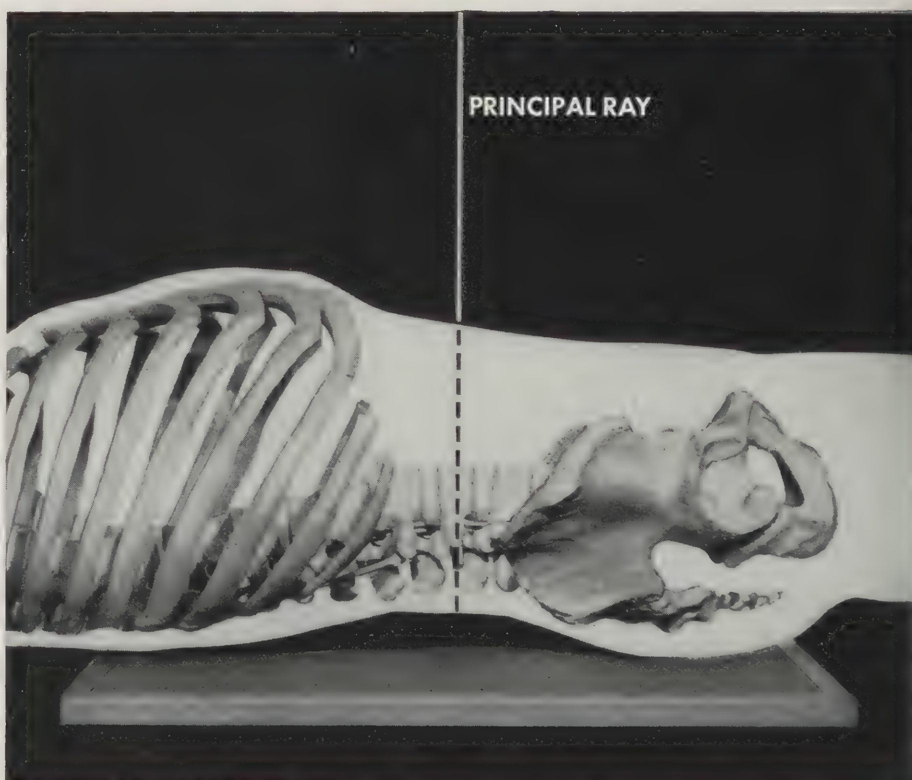
ADDITIONAL: To provide great focal-film distance, patient may be on litter, on the floor and tube elevated to provide as much as 72 inch focal-film distance.



DISTANCE: 60″	Measure through plane at level of lower border of manubrium																	
CMS. THICKNESS		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	74	76	78	80	82	84	76	78	80	82	84	80	82	84	80	82	84
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC		4						8					12			16		

Fig. 216.—ABDOMEN, (supine)





ANATOMICAL: Liver, kidneys, spleen, muscle shadows, in particular.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient supine, level of iliac crests 4 cm. below midlength of film. Midsagittal plane in midwidth of and perpendicular to film.

FOCAL SPOT: Align to center of film.

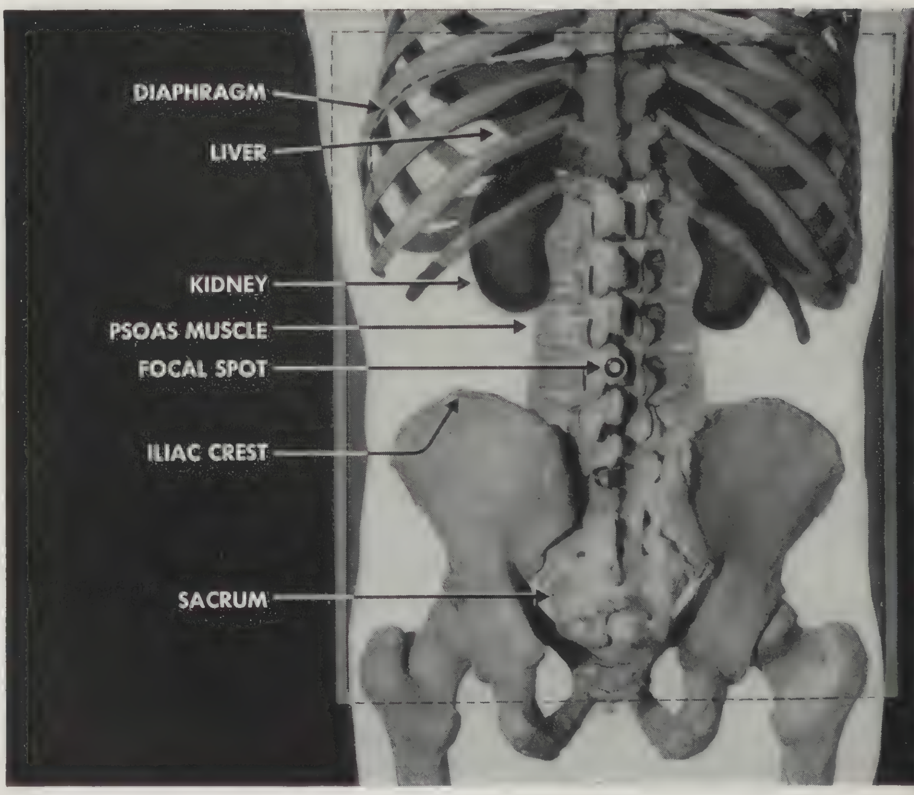
PRECAUTION: Avoid rotation (anterior superior iliac spines should be equal distance from table top).

ADDITIONAL: Grid. Respiration suspended in expiration.

DISTANCE: 30″ Measure through plane of iliac crests

CMS. THICKNESS		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	60	62	64	66	68	70	72	74	76	78	80	72	74	76	78	80
MA - SEC							40								80		

Fig. 217.—ABDOMEN, POSTERIOR-ANTERIOR



ANATOMICAL: Liver, kidneys, spleen, muscle shadows, spine, in particular.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient prone, level of the iliac crests 4 cm. below midlength of film. Midsagittal plane in midwidth of and perpendicular to film.

FOCAL SPOT: Align to spinous process of 3rd lumbar vertebra (half way between iliac crests to the 12th rib), to center of film.

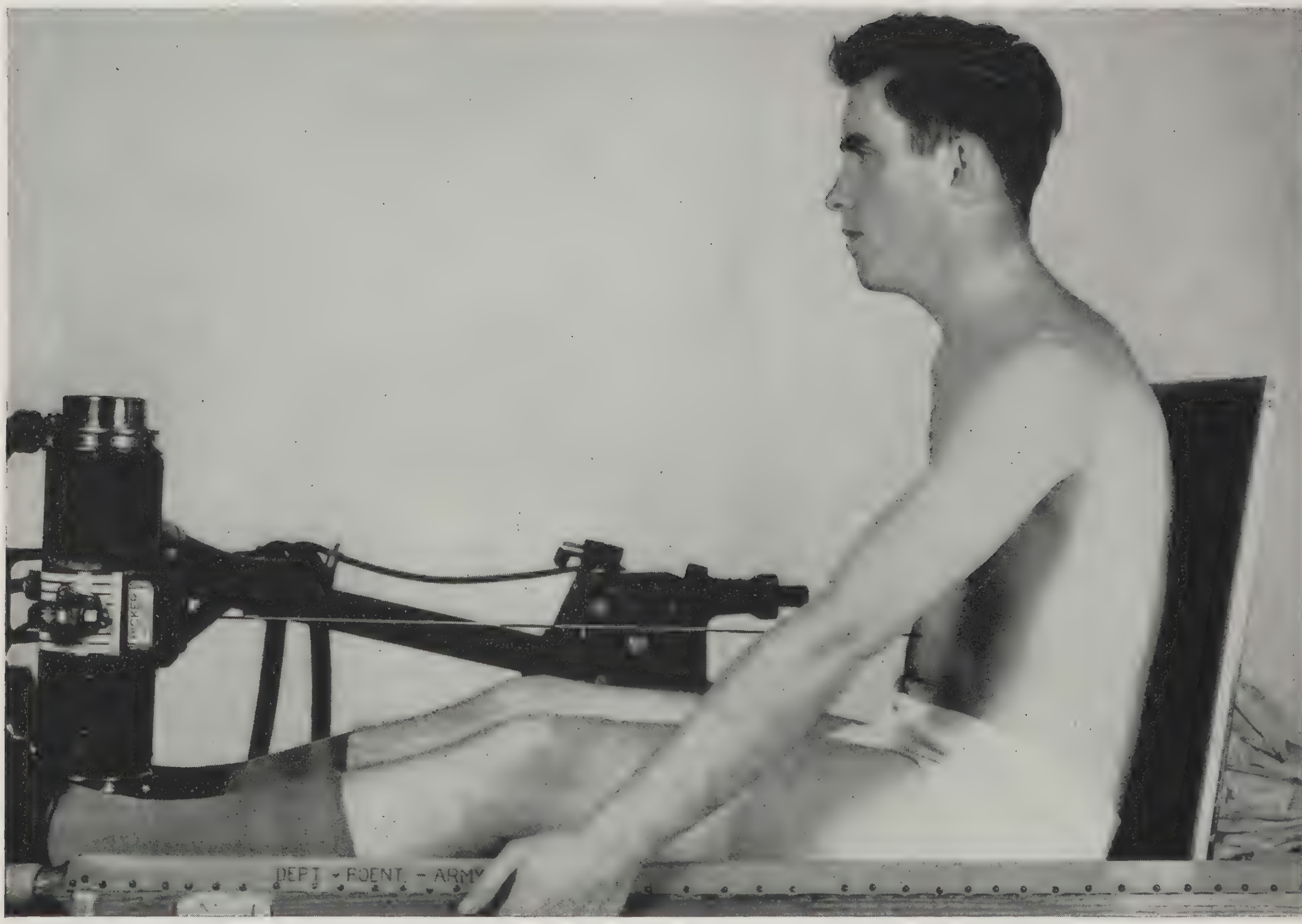
PRECAUTION: Avoid rotation of the trunk; respiration suspended in expiration.

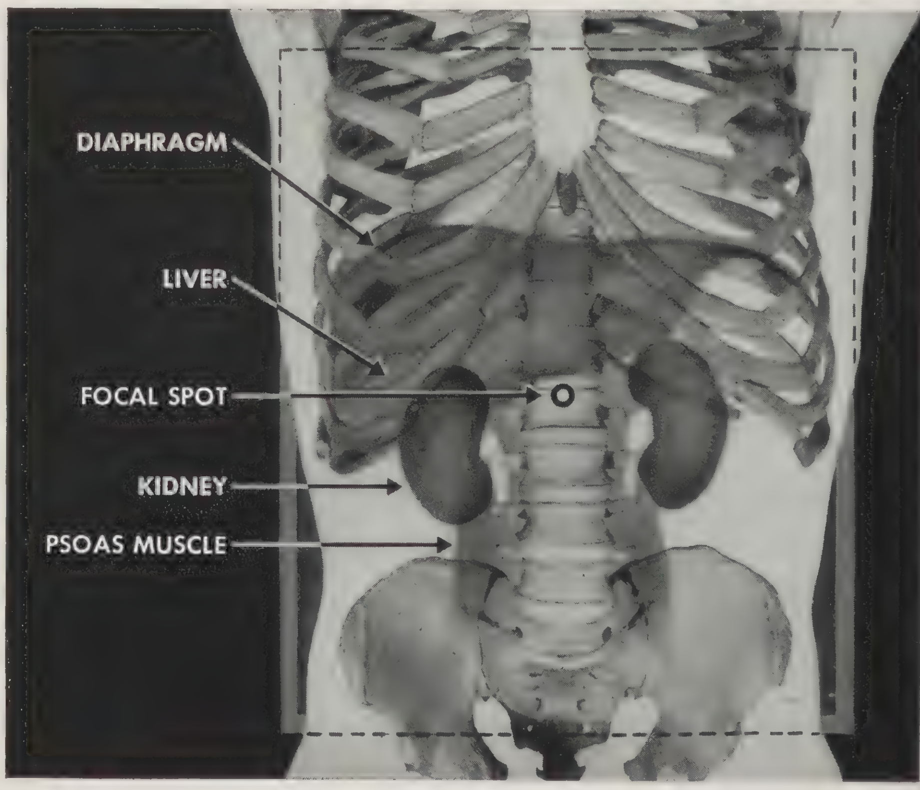
ADDITIONAL: Grid.

DISTANCE: 30″ — Measure through plane of iliac crests

CMS. THICKNESS		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders																
	with medium screens																
	with Army wafer grid	60	62	64	66	68	70	72	74	76	78	80	72	74	76	78	80
MA - SEC							40								80		

Fig. 218.—ABDOMEN (erect)





ANATOMICAL: As previously described, possibly, air under diaphragm.

FILM: 14 x 17 inch, lengthwise and vertical.

POSITION: Patient erect; film against back (held in place by sandbags, etc.); plane of iliac crests to plane 6 cm. below mid-length of film.

FOCAL SPOT: Align to center of film.

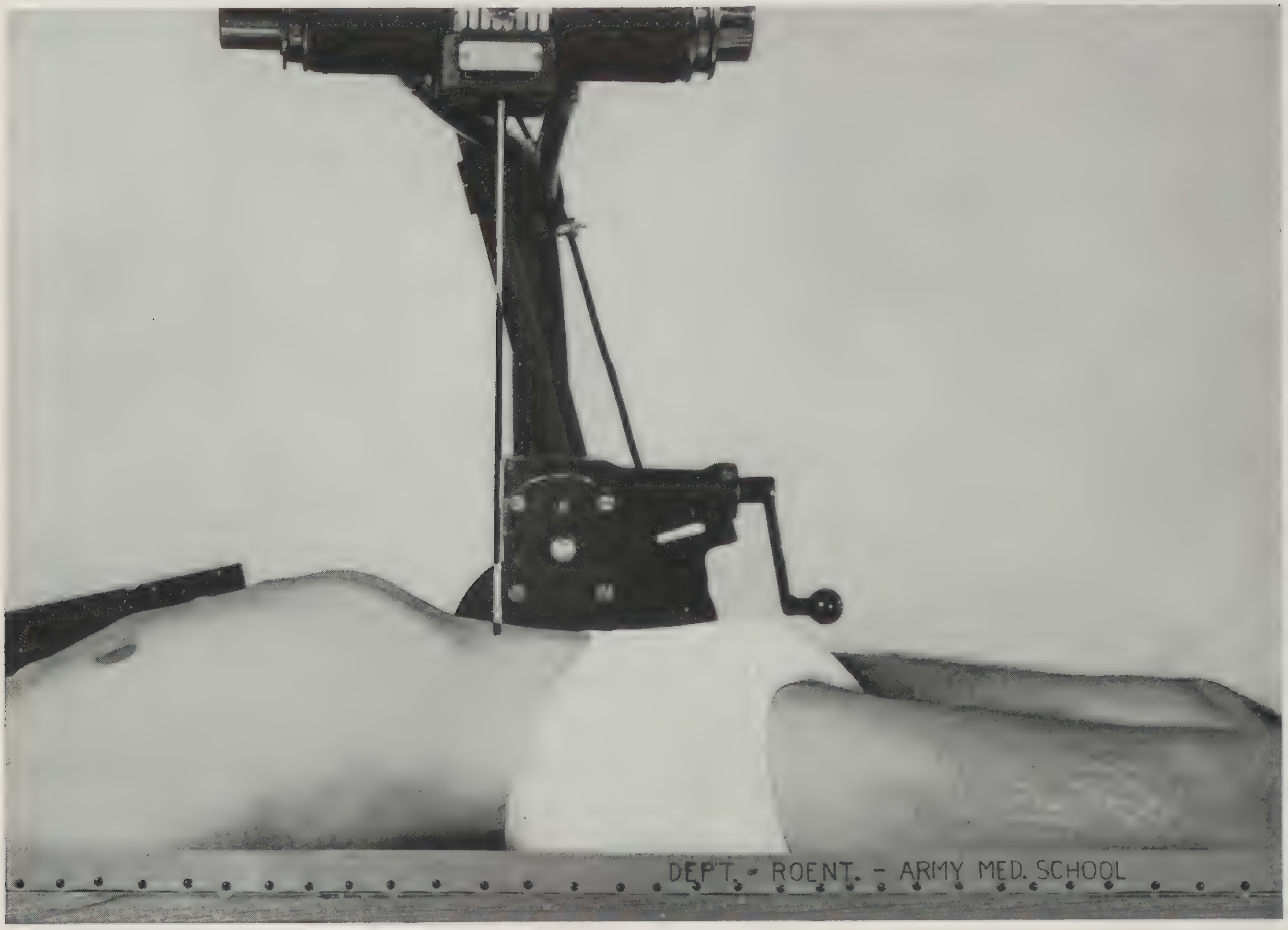
PRECAUTION: Respiration suspended in expiration; film high (to include diaphragms).

ADDITIONAL: Grid.

VARIATIONS: Lateral recumbent film often valuable, made with the subject lying on side (left), the beam being directed anteroposteriorly.

DISTANCE: 30″																	Measure through plane of iliac crests
CMS. THICKNESS		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	60	62	64	66	68	70	72	74	76	78	80	72	74	76	78	80
MA - SEC							40								80		

Fig. 219.—ABDOMEN (K.U.B.) ANTEROPOSTERIOR



ANATOMICAL: Kidneys, ureteral tracts, urinary bladder.

FILM: 14 x 17 inch, lengthwise.

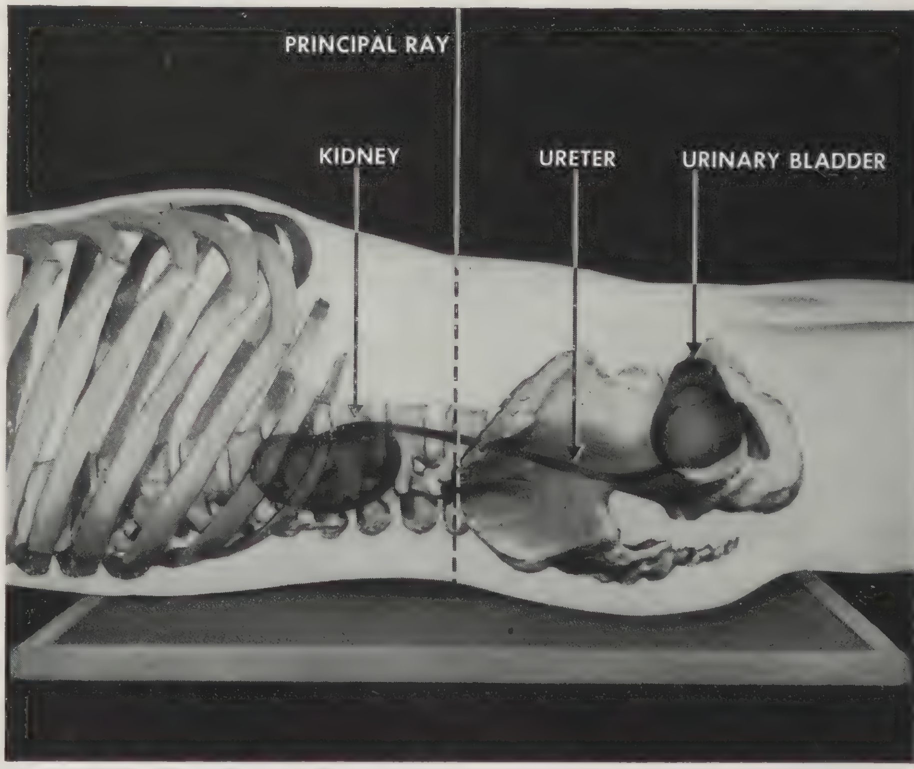
POSITION: Patient supine, trunk straight, level of iliac crests to midlength of film. Midsagittal plane perpendicular.

FOCAL SPOT: Align to center of film.

PRECAUTION: Flatten lordotic curvature (head and shoulders on pillows, knees flexed and raised); suspended respiration.

ADDITIONAL: Grid. For intravenous contrast studies, use compression band, lower abdomen.

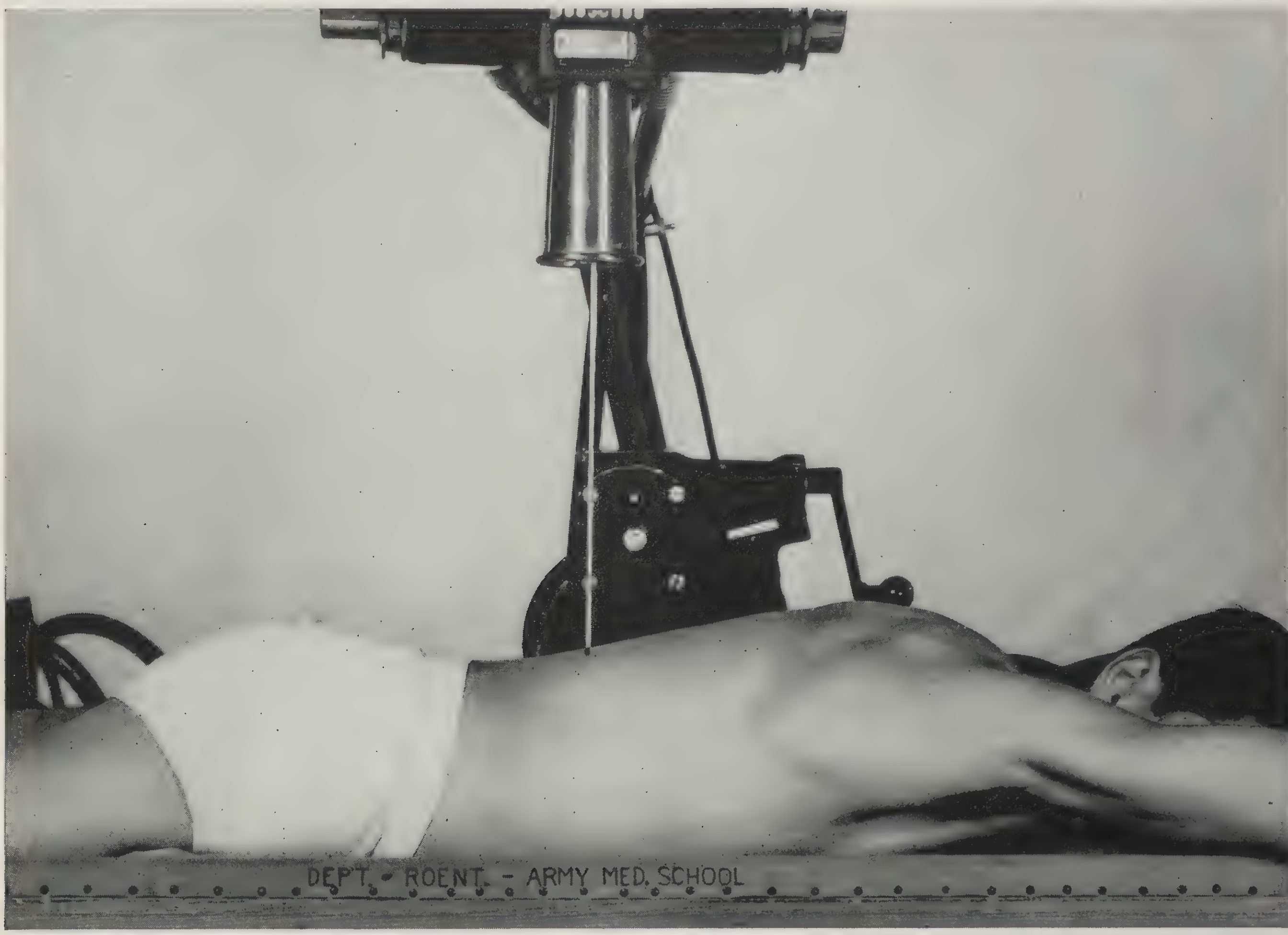
VARIATIONS: Erect or semierect studies frequently indicated. For kidneys alone, align 3 cm. above level of the iliac crests; for bladder, align 3 cm. above symphysis, with angulation caudad.

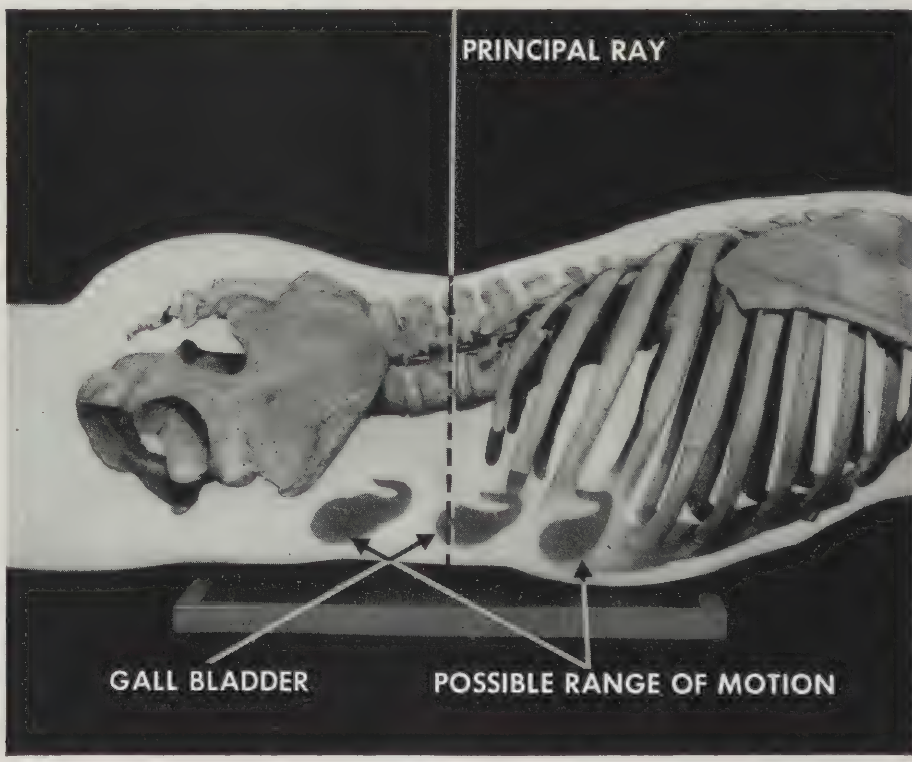


DISTANCE: 30″ Measure through plane of iliac crests

CMS. THICKNESS		15	16	17	13	19	20	21	22	23	24	25	26	27	28	29	30
VARIABLE KVP	with cardboard holders																
	with medium screens																
	with Army wafer grid	60	62	64	66	68	70	72	74	76	78	80	72	74	76	78	80
MA - SEC							40								80		

Fig. 220.—GALL BLADDER, POSTERO-ANTERIOR





ANATOMICAL: Gall bladder, right lobe of liver.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient prone, head resting on outstretched right forearm; left arm to side (slight rotation to the left); midscapular crossing of 11th rib to center of film. Preliminary study-subsequently, change to localization of gall bladder.

FOCAL SPOT: Align to center of film.

PRECAUTION: Suspended respiration, trunk straight.

ADDITIONAL: Grid; cone or extension cylinder.

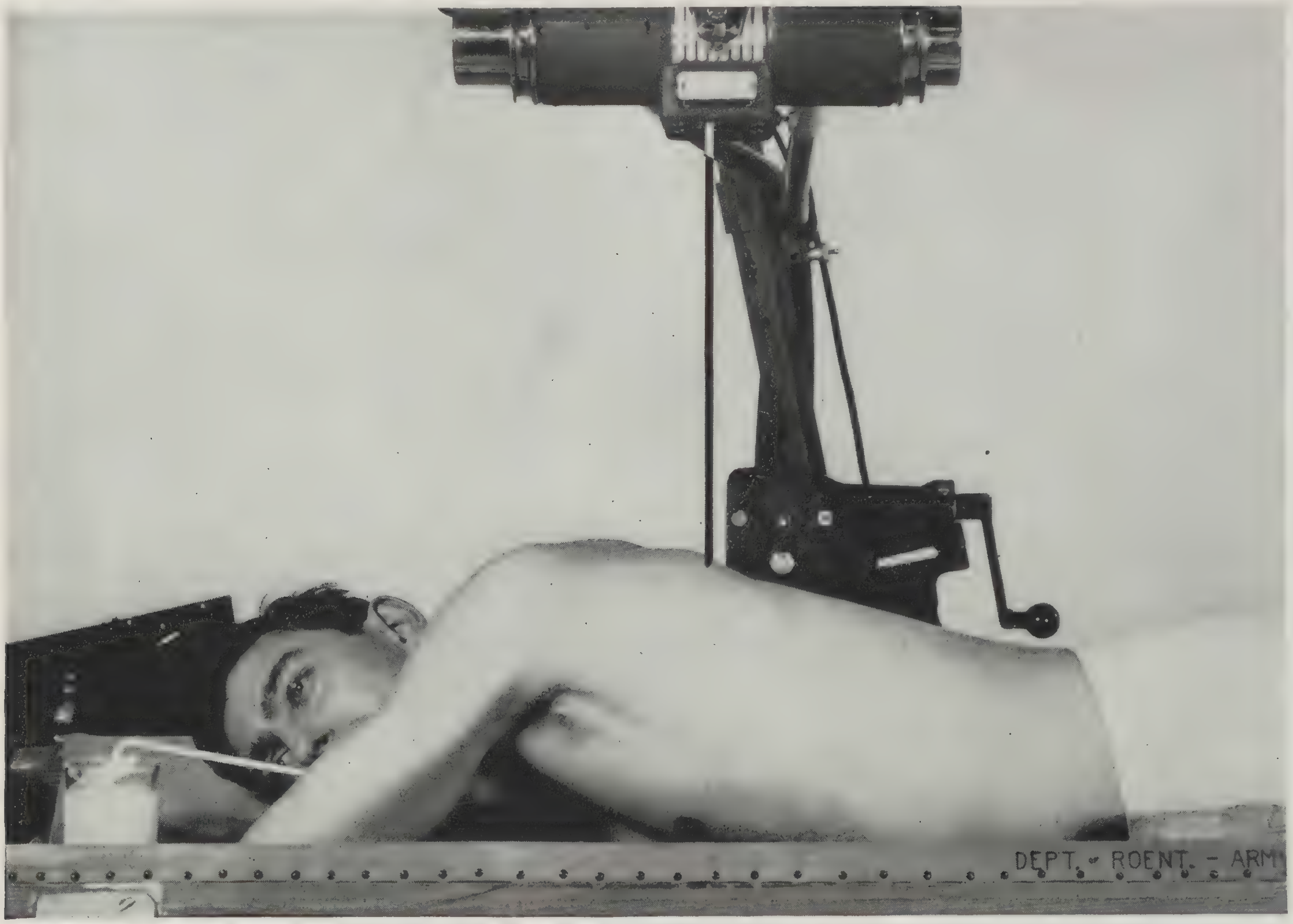
VARIATIONS: Occasionally, upright position may be indicated.

DISTANCE: 30″ Measure through abdomen over 12th rib

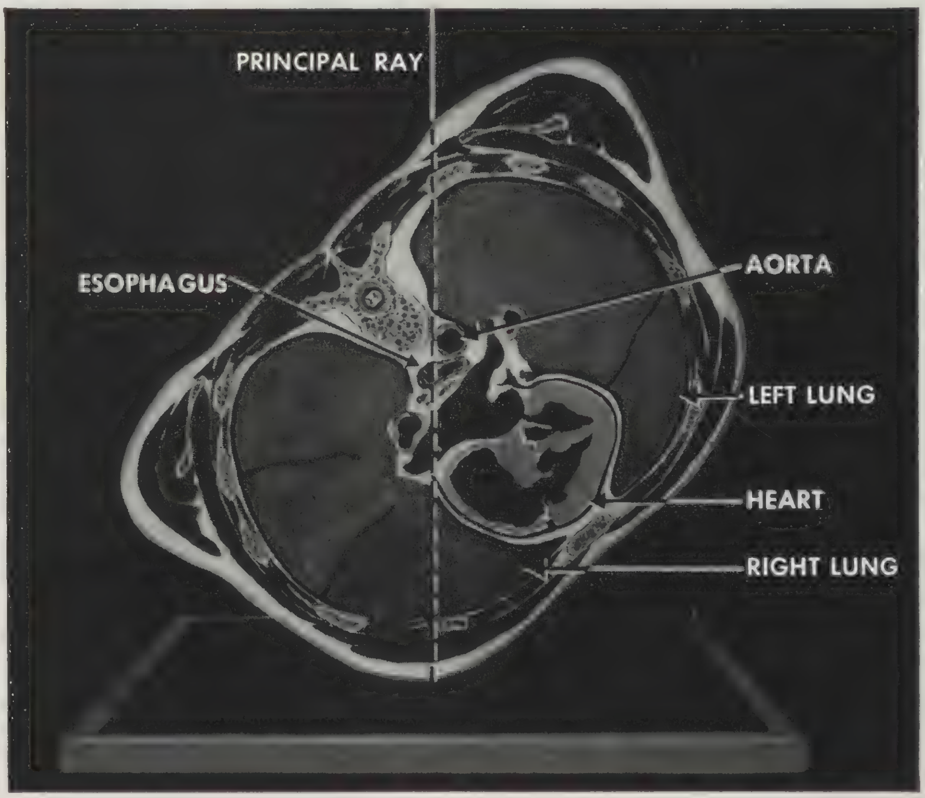
CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
VARIABLE KVP	with cardboard holders																		
	with medium screens																		
	with Army wafer grid	56	58	60	62	64	66	68	70	72	74	76	68	70	72	74	76	78	80
MA - SEC							25									50			

AUXILIARIES: CONE or extension cylinder.

Fig. 221.—ESOPHAGUS, RIGHT ANTERIOR OBLIQUE



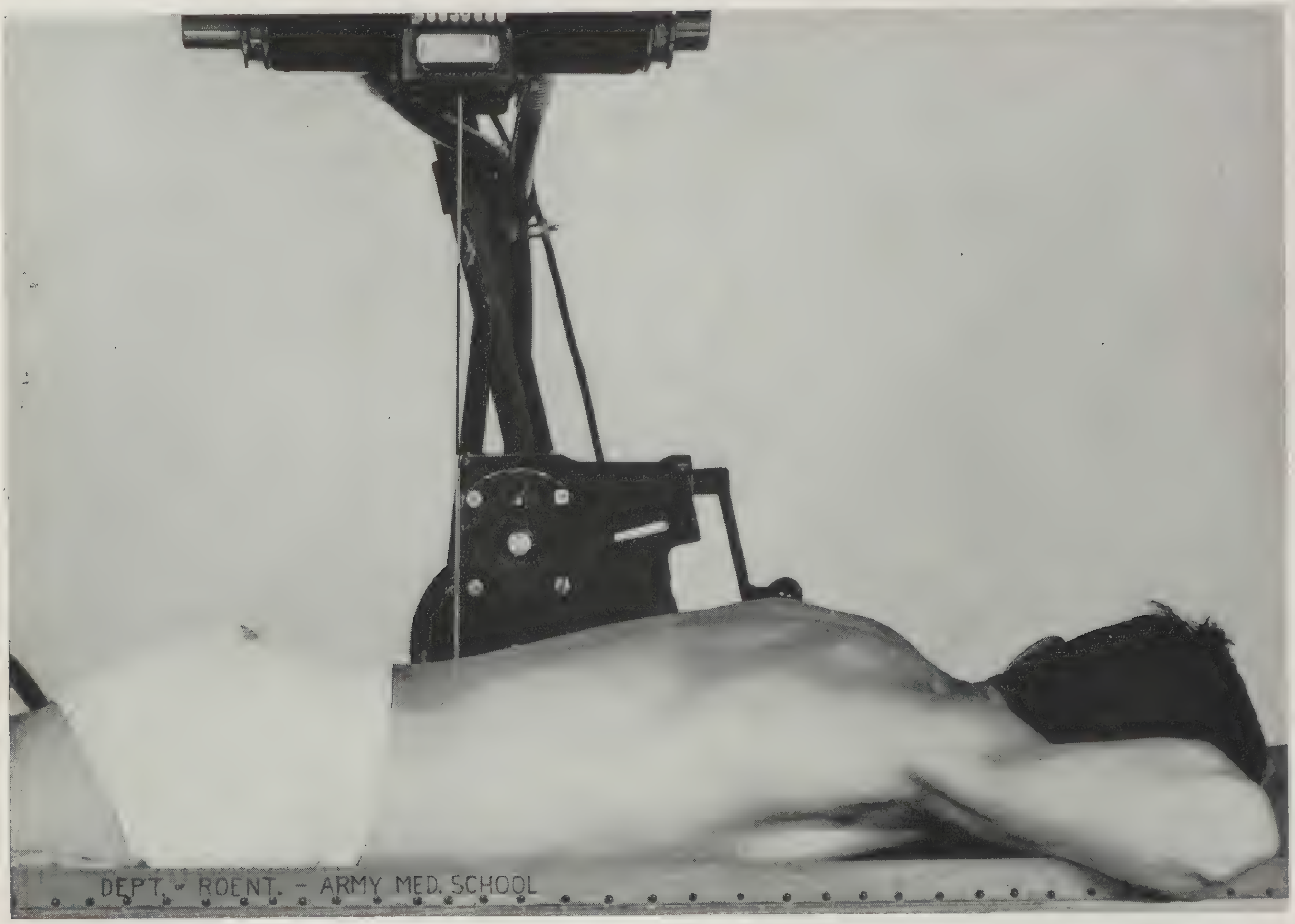
ANATOMICAL: Pharynx, larynx, heart and tracheal bifurcation, in particular.
FILM: 14 x 17 inch, lengthwise.
POSITION: Patient prone, rotated 40 to 50°, right side in contact with cassette; right arm at side, left hand under head; left hip supported on sandbag. Level of mandible to upper border of cassette.
FOCAL SPOT: Align to point medial to inferior angle of left scapula to center of film.
PRECAUTION: Respiration suspended in forced inspiration. Exposure made during ingestion of barium.
VARIATIONS: For study of mucosal pattern of lower esophagus, use modified Trendelenberg position (head lowered, feet elevated). An upright right anterior oblique position recommended for study of obstructive lesions.



DISTANCE: 30″ — Measure plane through 6th thoracic vertebra, obliquely

CMS. THICKNESS		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	60	62	64	66	68	70	72	74	76	78	70	72	74	76	78	70	72	74	76	78
	with Army wafer grid	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MA - SEC							9							18					36		

Fig. 222.—STOMACH, POSTERO-ANTERIOR



ANATOMICAL: Stomach, 1st and 2nd portions of duodenum, in particular.

FILM: 10 x 12 inch, unless otherwise specified at roentgenoscopy.

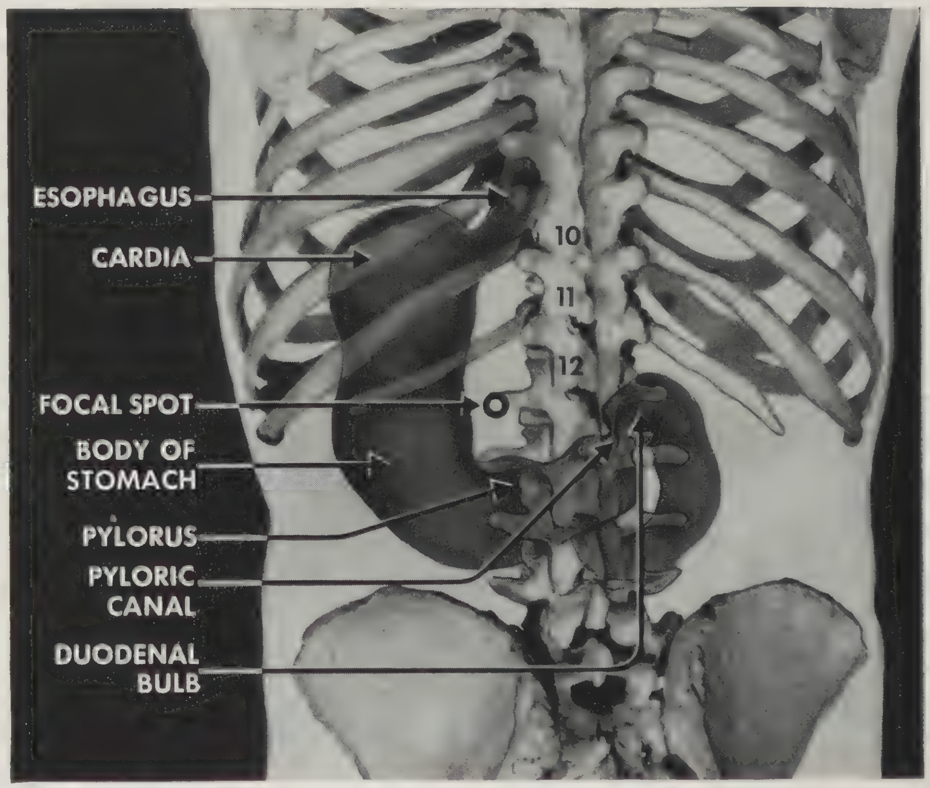
POSITION: Patient prone, cassette under left upper quadrant, its lower border to level of iliac crest—or as indicated by marking at time of roentgenoscopy; non-opaque pads may be used under the chest and thighs.

FOCAL SPOT: Align to center of film.

PRECAUTION: Respiration suspended in inspiration.

ADDITIONAL: Cone recommended; grid optional.

VARIATION: Angulation requirements may vary (proper angulation should be determined at roentgenoscopy). Spot and pressure cone films may be indicated.

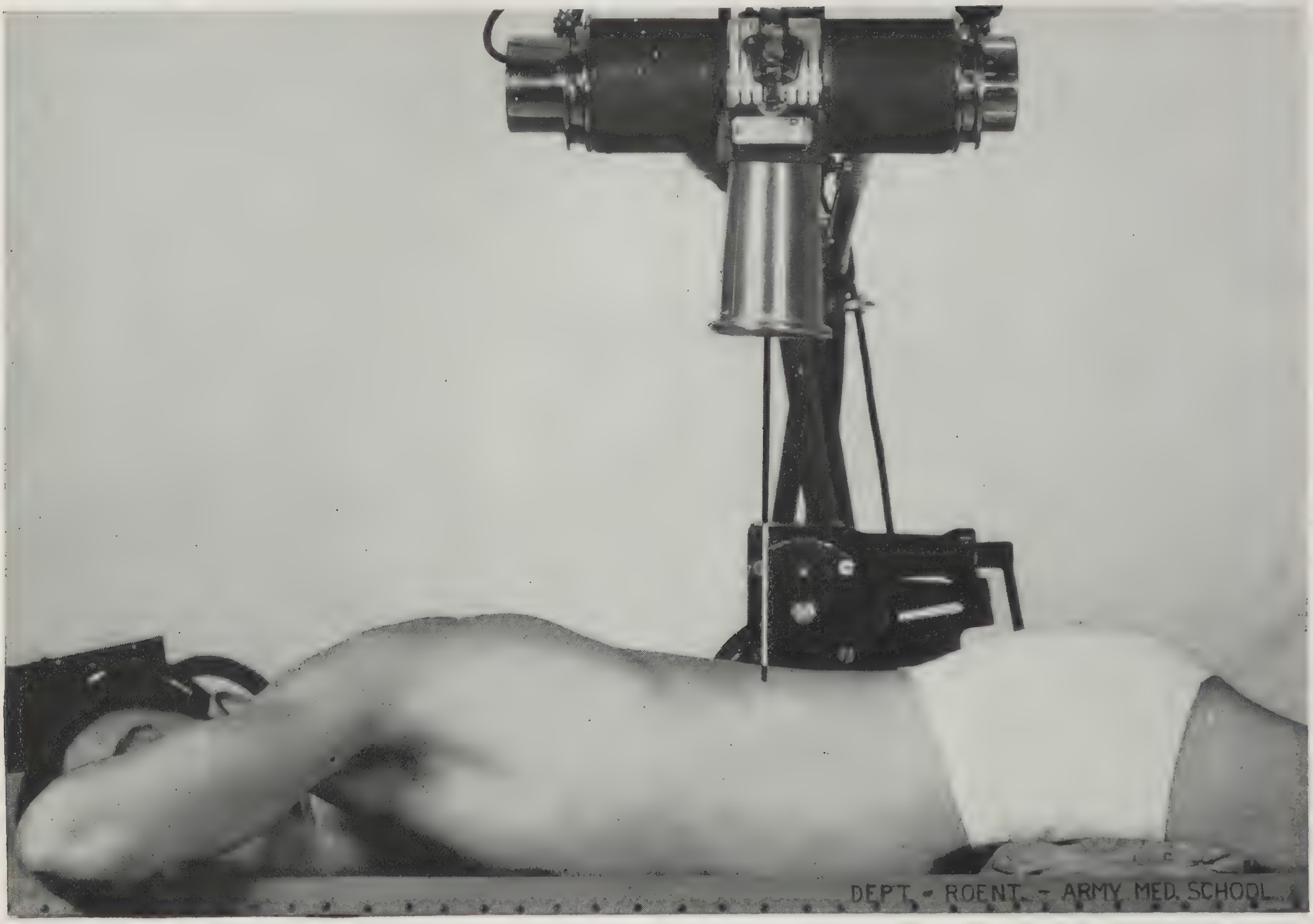


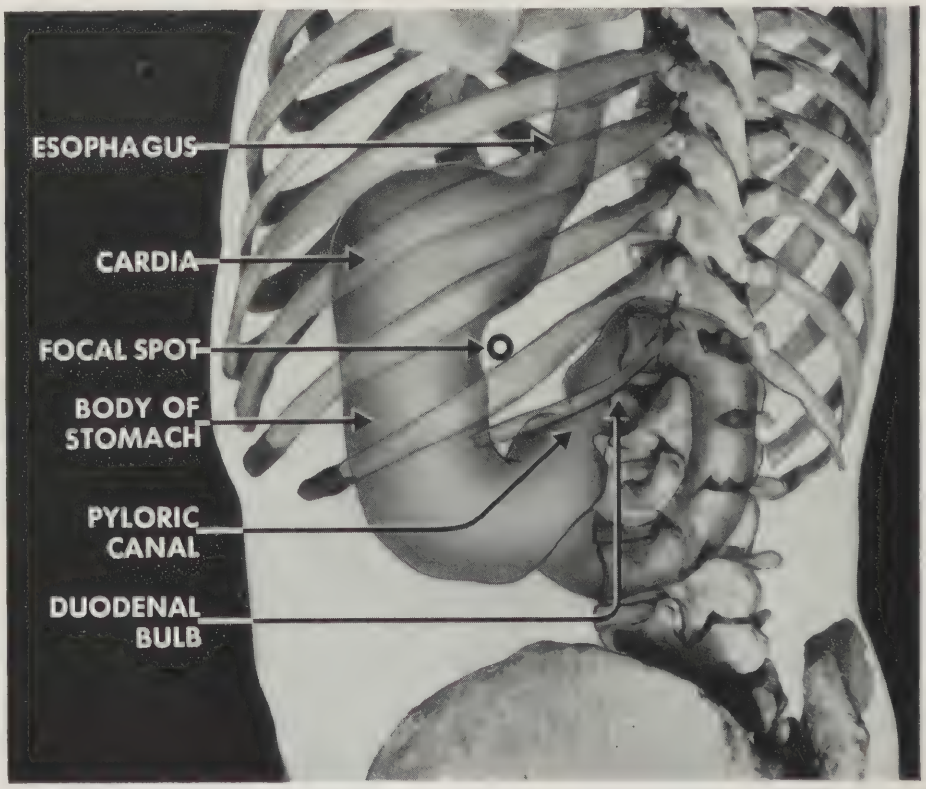
DISTANCE: 30″ Measure through plane of principal ray

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	66	68	70	72	74	76	78	80	82	84	76	78	80	82	84
MA - SEC		25										50				

AUXILIARIES: CONE.

Fig. 223.—STOMACH, RIGHT ANTERIOR OBLIQUE





ANATOMICAL: Stomach.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient semiprone, rotated 30 to 45° to right side; right arm at side, left arm extended alongside head; left knee flexed and sandbag under left hip; lower border of cassette at iliac crest.

FOCAL SPOT: Align to skin marking made at roentgenoscopy to center of film.

PRECAUTION: Suspended inspiration.

ADDITIONAL: Grid.

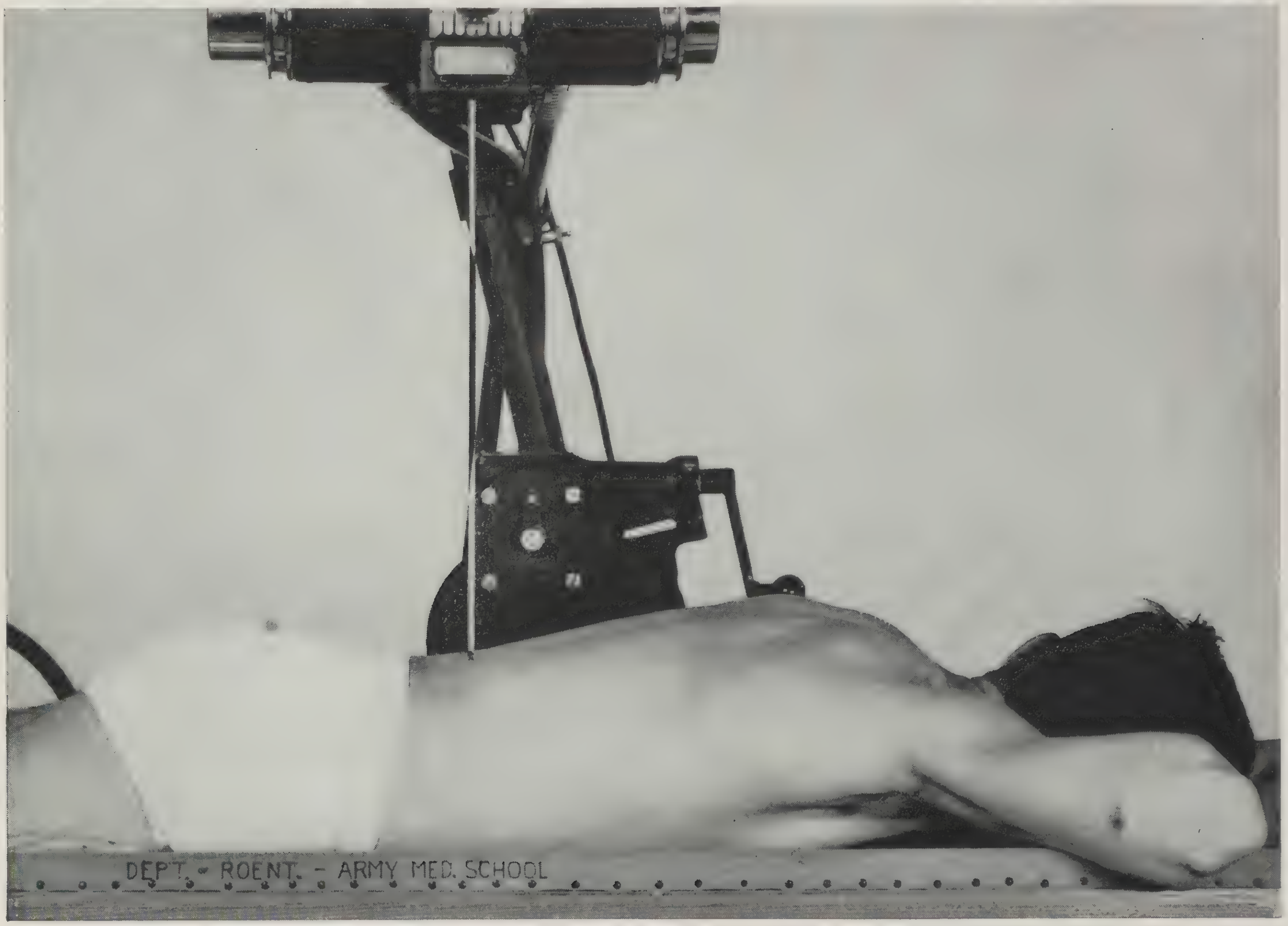
VARIATION: True postero-anterior films are made in prone position, aligning to point 8 cm. to left of spinous process of 2nd lumbar vertebra. For suspected diaphragmatic hernia, tilt patient 15°, head down, and make exposure with suspended expiration.

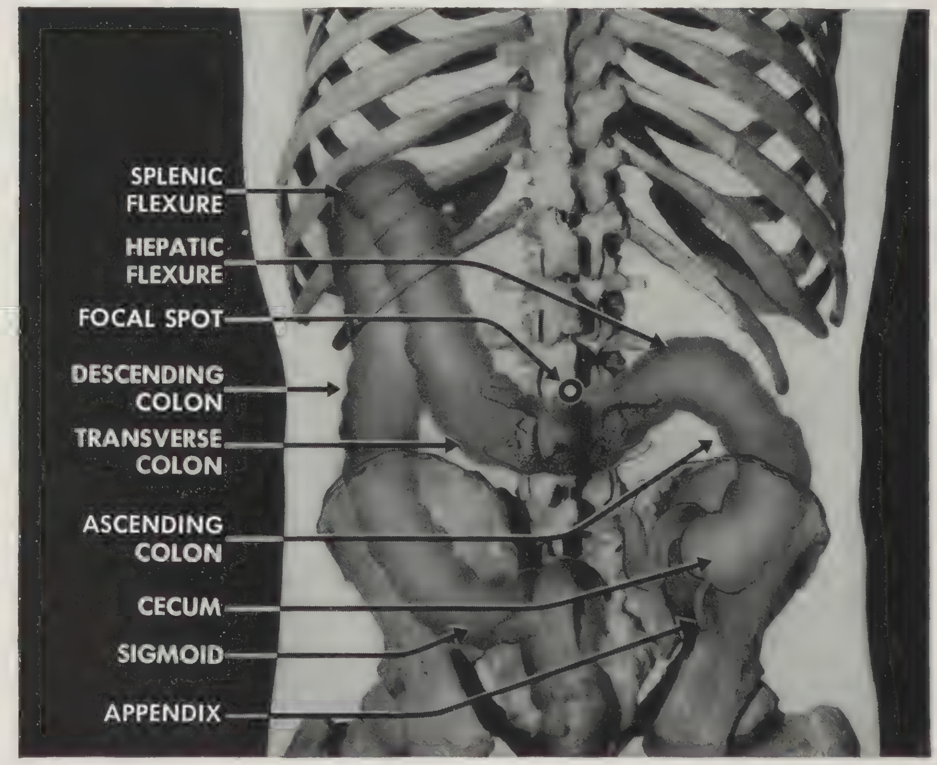
DISTANCE: 30″ — Measure through plane of principal ray

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
VARIABLE KVP	with cardboard holders															
	with medium screens															
	with Army wafer grid	66	68	70	72	74	76	78	80	82	84	76	78	80	82	84
MA - SEC		25										50				

AUXILIARIES: CONE.

Fig. 224.—LARGE BOWEL POSTERO-ANTERIOR





ANATOMICAL: Colon; rectum, distal small intestines, in particular.

FILM: 14 x 17 inch, lengthwise.

POSITION: Patient prone; level of iliac crests to midlength of film.

FOCAL SPOT: Align to center of film.

PRECAUTION: Suspended expiration.

ADDITIONAL: Grid.

DISTANCE: 30″ — Measure through plane of iliac crests

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	66	68	70	72	74	76	78	80	82	84	76	78	80	82	84
MA - SEC						25								50		

Fig. 225.—POSITIONING FOR BARIUM-FILLED COLON (see fig. 224)

LARGE BOWEL POSTEROR-ANTERIOR

(double contrast enema)

ANATOMICAL: Colon after evacuation of barium mixture (mucosal pattern), in particular.

FILM: 14 x 17 inch, lengthwise. Extremely large patients may require more than one film or even crosswise placement.

POSITION: Patient prone; plane of iliac crests to midlength of film.

FOCAL SPOT: Align to center of the film; (anatomical centering may vary with type of body habitus from 2nd lumbar vertebra to 5th lumbar vertebra).

PRECAUTION: Avoid rotation or lateral flexion of the trunk.

ADDITIONAL: Grid. Respiration suspended.

DISTANCE: 30″ Measure through plane of iliac crests

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
VARIABLE KVP	with cardboard holders															
	with medium screens															
	with Army wafer grid	66	68	70	72	74	76	78	80	82	84	76	78	80	82	84
MA - SEC						25								50		

LARGE BOWEL POSTERO-ANTERIOR

(post evacuation)

ANATOMICAL: Colon after evacuation of barium suspension and the injection of air.

FILM: 14 x 17 inch, lengthwise. Extremely large patients may require more than one film or even crosswise placement.

POSITION: Patient prone, plane of iliac crests to midlength of film.

FOCAL SPOT: Align to center of film (anatomically this may vary according to habitus of the individual).

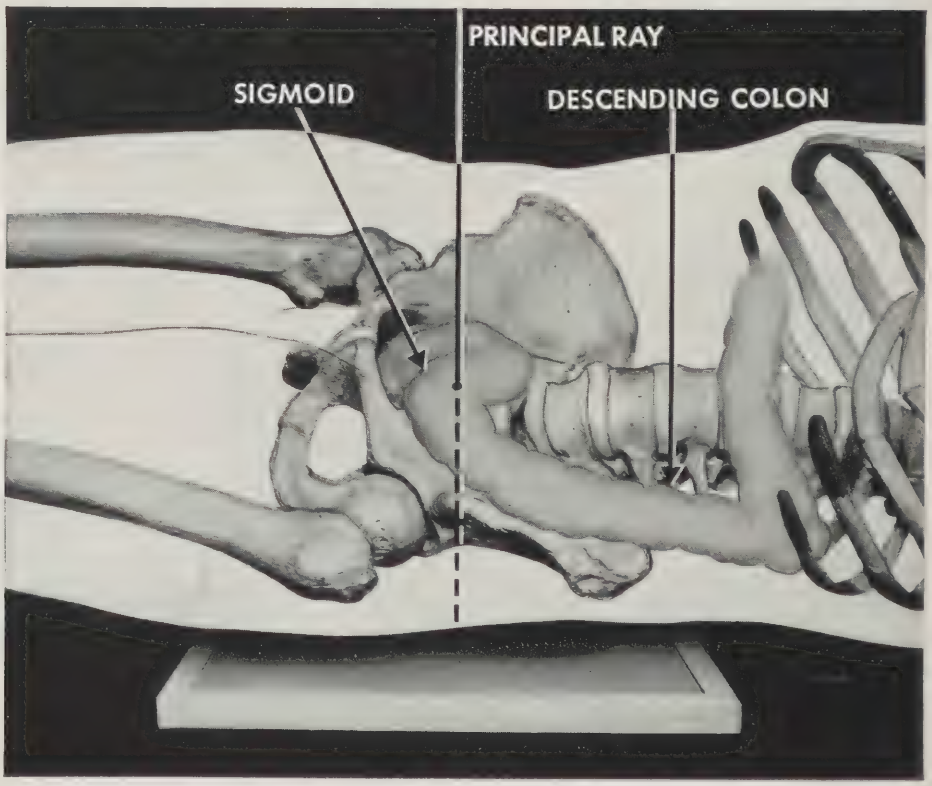
PRECAUTION: Voltage must be lowered at least 6 to 8 kvp because of the presence of air as a contrast medium in the colon. Respiration suspended in expiration.

ADDITIONAL: Grid.

DISTANCE: 30″ — Measure through plane of the iliac crests

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
VARIABLE KVP	with cardboard holders	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with medium screens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	with Army wafer grid	58	60	62	64	66	68	70	72	74	76	78	80	72	74	76
MA - SEC		25												50		

Fig. 226.—LARGE BOWEL, ANTEROPOSTERIOR OBLIQUE OF SIGMOID



ANATOMICAL: Sigmoid overlying the sacrum and left wing of ilium.

FILM: 10 x 12 inch.

POSITION: Patient supine. Left hip down; right hip and trunk rotated 30 to 60° anteriorly (as indicated by roentgenoscopy).

FOCAL SPOT: Align to center of film. Place area outlined roentgenoscopically over the center of the film.

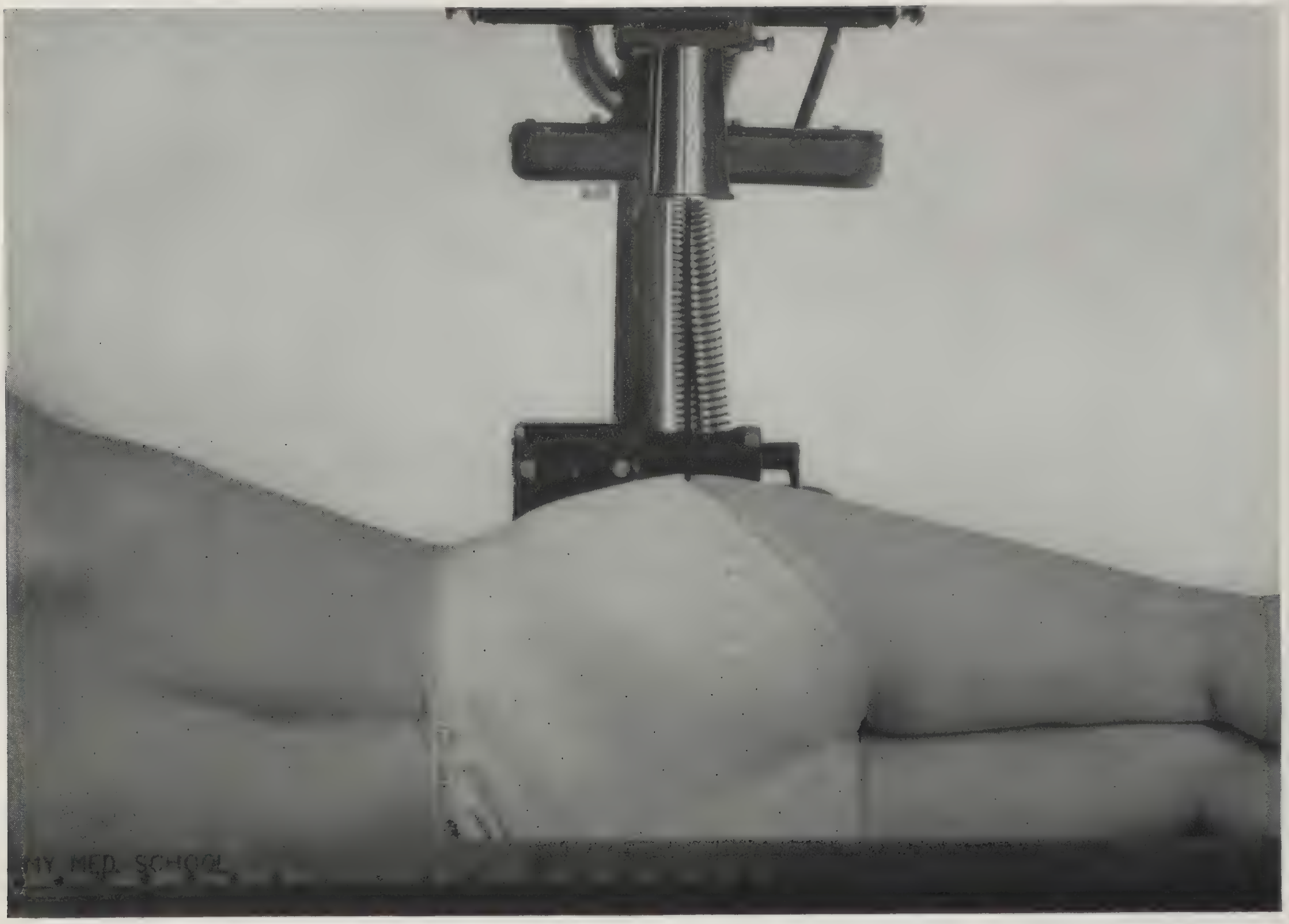
PRECAUTION: See that oblique position set up roentgenoscopically is maintained. Respiration suspended in expiration, or as specified by roentgenoscopist.

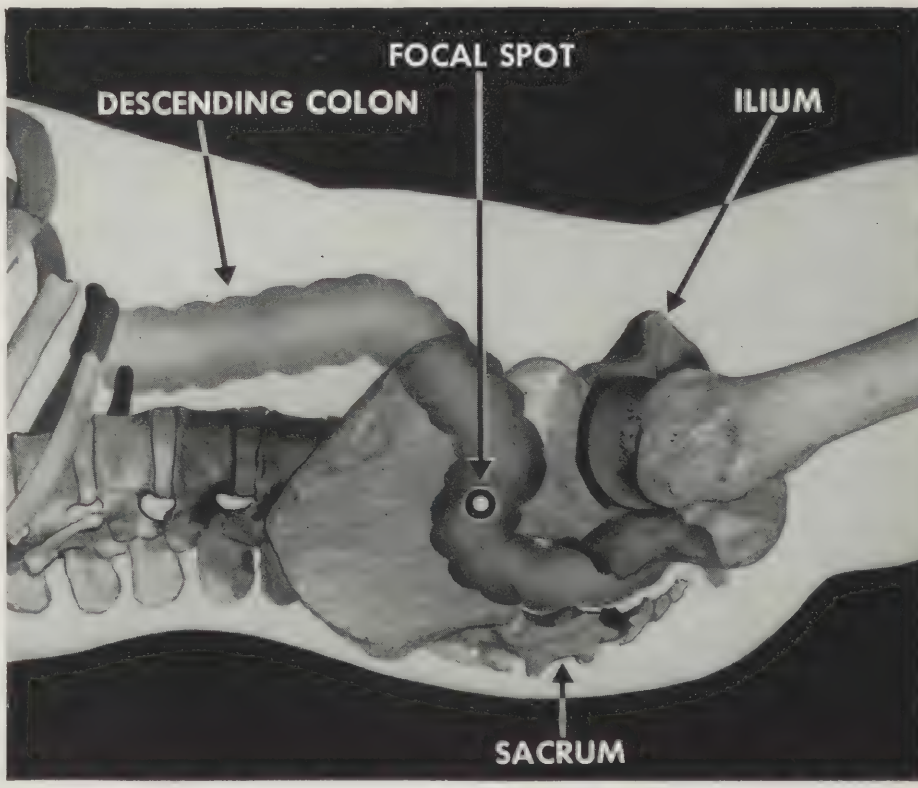
ADDITIONAL: Grid.

DISTANCE: 30″ — Measure through plane of iliac crests

CMS. THICKNESS		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
VARIABLE KVP	with cardboard holders															
	with medium screens															
	with Army wafer grid	66	68	70	72	74	76	78	80	82	84	76	78	80	82	84
MA - SEC							25							50		

Fig. 227.—RECTUM, LATERAL





ANATOMICAL: Rectal ampulla, rectum, sigmoid and a portion of the descending colon.

FILM: 10 x 12 inch, lengthwise.

POSITION: Patient in left lateral recumbent position. Knees partially flexed for support, right hip truly vertical above the left; plane of iliac crests to upper border of film.

FOCAL SPOT: Align to a point about 9 cm. anterior to skin over midportion of the sacrum and 10 cm. below midcrest of ilium.

PRECAUTION: Respiration suspended. Patient should be in a true lateral position.

ADDITIONAL: Grid.

DISTANCE: 30″ Measure through path of central ray

CMS. THICKNESS		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
VARIABLE KVP	with cardboard holders																
	with medium screens																
	with Army wafer grid	74	76	78	80	72	74	76	78	80	82	84	76	78	80	82	84
MA - SEC			150						300						450		

AUXILIARIES: CONE.

CHAPTER 11

SPECIAL TECHNIQUES

253. GENERAL. Special roentgenographic techniques include a vast number of procedures devised to supplement routine roentgenography. The techniques of principal interest for military requirements include stereoscopy, use of opaque media, serialography, kymography, body-section roentgenography, photoroentgenography, isolation, and sterile technique. It must be emphasized that the foregoing mentioned techniques by no means cover all the special requirements of diagnostic roentgenology. In addition, roentgenoscopy is also described; however, it should not be regarded as a special roentgenographic procedure for it is used routinely. It is suggested that proper texts be consulted for more detailed descriptions of procedures required in special situations.

254. STEREOSCOPY. a. General. A single roentgenogram is viewed as a shadow graph. There are two dimensions concerned with it, length and width. In order to provide perception of the third dimension, depth, it is ordinarily necessary to accomplish two exposures. These two exposures must be made without movement of the patient. For the second exposure, a second film is positioned just as the first one was positioned with respect to the patient. Only the position of the tube is changed. The changing of position of the X-ray tube between the two exposures accomplishes two distinct point-source projections of the roentgenographic image. These two point-source projections are in effect comparable to the viewings provided for the right and the left eye, respectively. (See fig. 228.) In fact, when handling

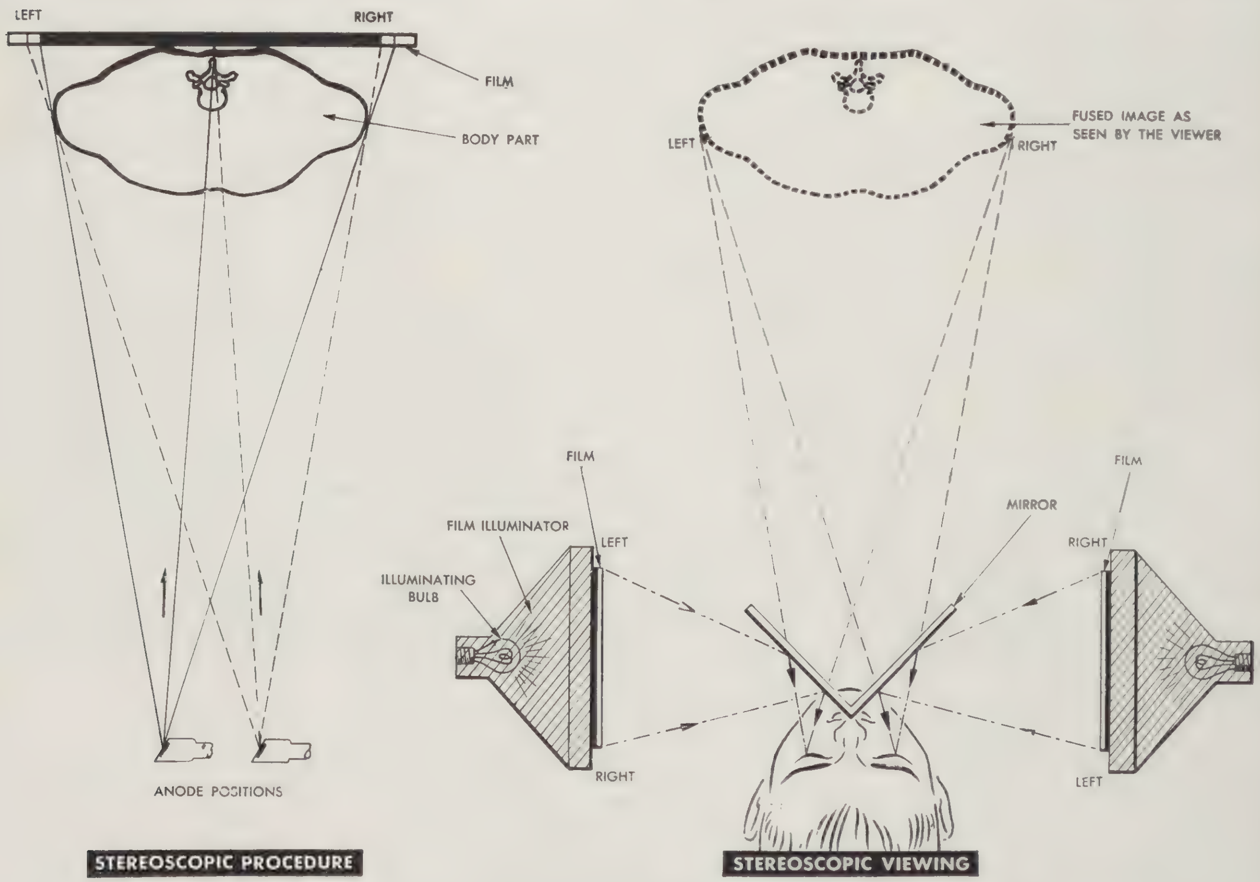


Figure 228. Stereoscopy.

the two roentgenograms concerned with stereoscopic viewing, one should always have in mind the position of the X-ray tube with respect to the patient and the film, for the first exposure, and then the position of the X-ray tube in relation to the patient and the film, for the second exposure. This correlation is of importance because there are at least 12 likely procedures which one might follow in positioning the two films for viewing with a stereoscope and yet with only two of these, is it possible to obtain *true* stereoscopic vision. With the other 10 or more procedures (additional possibilities would less likely be followed), the fused stereoscopic image will either be flat, of shallow depth, or of untrue anatomical relations; these are pseudo-stereoscopic images. They are optical illusions. Viewing them is very fatiguing. Worse than that, they may lead to erroneous reports with respect to locating pathology. True stereoscopy provides easy viewing. It provides a depth perception of true anatomical relations. True versus pseudo-stereoscopic viewing is especially important in the Army where hundreds of cases may have to be studied each day.

b. Geometric considerations. In order to obtain the most true proportionality with respect to the three dimensions, height, width, and depth, it is necessary that the ratio relationship between the interpupillary spacing and the distance at which the roentgenographic image is viewed be similar to the ratio relationship between the distance of tube shift (that is, spacing between the two positions of the focal spot) and the focal-film distance. These relations must be as similar triangles. The average spacing between the pupils of the eyes of an adult is 2½ inches. The average viewing distance is 25 inches. With such conditions, there is the ratio of 1 to 10. For such viewing, the shifting of the focal spot should likewise be 1 to 10; the tube shift should be 10 percent of the focal film distance.

c. Roentgenographic exposures. The patient is positioned as for ordinary roentgenography. The focal-film distance may vary; it may be as short as 18 inches (mastoids); it may be the conventional 30 to 36 inches or it may be increased to 48 to 72 inches or more. Depending upon the focal-film distance selected, the distance of tube shift and the initial positioning of the tube with respect to the part to be roentgenographed, varies. As mentioned above, the tube shift is ordinarily 10 percent of the focal-film distance. The initial position of the tube should be above or below or to either side of the usual site for centering and at a distance from the usual site of centering, to the extent of half of the tube shift distance. An exposure is made with the usual factors. The film is removed and replaced by another. For the second exposure, the focal spot of the X-ray tube is positioned directly across and away from the ordinary site of centering and again at a distance from that site equal to half of the range of tube shift. A second exposure is made using the same technical factors as before. The direction of the tube shift depends upon the viewing objective. Ordinarily, the tube is shifted in the plane which provides for viewing from two aspects about contours of opacity (that is, in the case of the lungs—this shift is usually vertical to provide for viewing around the ribs, yet for a density in the thoracic vertebral gutter the shift should be transverse to provide viewing through tangents of the vertebral column).

d. Film processing. The two films should be processed at the same time. The ordinary processing procedure is followed.

e. Viewing apparatus. Viewing of a pair of films for depth perception is ordinarily accomplished with the assistance of a stereoscope. There are two general types of stereoscopes: the mirror type and the prism type. In the field a simple modification of the mirror type of stereoscope can be developed with arrangement of two view boxes and two small mirrors; that is, ordinary shaving mirrors. (See fig. 229.) The films must be positioned for viewing in accordance with the design of the stereoscope, in order to obtain true stereoscopic vision.

f. Positioning of the films for viewing. Though short cut practices are numerous, the dangers of obtaining pseudo-stereoscopic vision rather than true stereoscopic vision are so great that it is best to follow a system which will provide for true depth perception, regardless of the part which is being studied and regardless of the direction of the tube shift. The following procedure can be relied upon:

(1) Superimpose the film images, holding the two films in view so that the anatomical relations in the roentgen images, with respect to the eyes, duplicate the anatomical relations of the patient with respect to the position of the tube. For instance, in the case of the chest, if a P-A projection were made, ordinarily (that is, unless the subject have a dextrocardia) the films should be held so that the apex of the heart of the roentgen image be to the examiner's left; whereas, if an A-P projection had been made, the films should be held so that the apex is to the examiner's right.

(2) With the edges of the films even, note the position of the images in relation one to the other and thereby decide as to the direction of tube shift (that is, if one image is higher than the other, the evidence is that the tube was shifted vertically; whereas, if one image is to the right or the left of the other, the evidence is that the tube was shifted transversely in relation to the patient).

(3) Rotate the films (if necessary) so that the plane of the image shift is parallel to the plane of the eyes (that is, if the tube were shifted vertically in relation to the patient, the films must be rotated 90°—either to the right or to the left—whereas, if the tube were shifted transversely in relation to the patient, the plane of the shift is already parallel to

the eyes and the films would not be rotated).

(4) When using the mirror type of stereoscope, it is necessary to compensate for the mirror image. This is accomplished by rotating the films 180° in the *horizontal plane*. If a prism type of stereoscope is used, the films are *not* rotated.

(5) Having the films superimposed with their edges even, withdraw with the right hand that film of which the image is closer to the right and place it in the viewing box, on the examiner's right; merely carry the other film over to the viewing box on the examiner's left.

g. Confirmation of true stereoscopy. The films of a stereo pair are positioned properly only when with stereoscopic viewing there be *easy* depth perception and only if the projected image reestablishes the relations of the part of the patient with respect to the tube. For example, if a P-A projection were made, the view must be from the posterior planes *to* the anterior planes; if a right lateral projection were made, the view must be from the left side *to* the right, with the perception that the latter be closer to the film than to the plane of any identification that may not have been placed upon the film.

h. Image deficiencies. Several types of defect of the image may occur. Typical defects can easily be explained. For instance, if the anatomical relations are reversed (that is, a left-sided heart projecting as a right-sided heart, etc.), the evidence is that step (1) or step (4) above has been violated, (that is, that a P-A projection has been handled as if it were an A-P projection; that a right lateral projection has been handled as if it were a left lateral projection, etc., or that no compensation has been provided for the mirror shift of the image). If the projected image is flat, with little or no depth perception, the evidence is that steps (2) and (3) have been violated. If there be annoying depth perception, whereby it is difficult to decide as to whether the anterior plane of the part be closer to the examiner's eyes, or farther, as compared with the posterior planes; or where one anatomical plane is projected in malrelation with other parts (for example, in the case of the chest, the clavicles projecting as if they were perforating the midlung zones), the evidence is that step (5) has been violated.

i. Stereoscopy with photoroentgenography. The above described requirements indicate that the film must be positioned properly in relation to the position of the focal spot of the X-ray tube; furthermore, that the axis of tube shift must be considered. In the final viewing, there is one particular image which should be viewed by the right eye while the other image must be viewed by the left eye. All of those requirements pertain to roentgenographic viewings as well as to viewing of the more conventional film studies. The relationship of the image for the right eye to that for the left eye is especially important when the two images are projected in tandem onto a single film, as in photoroentgenography. In this connection, the Army has adopted the 4- by 10-inch film, with which two 4- by 5-inch images are obtained. One of these might be described as the "lead image"; the other, as the "follow image." In this work, the direction of film shift must be coordinated with respect to the direction of X-ray tube shift. The designs of vertical tube columns vary. With some, the X-ray tube shifts from a low to a high position; whereas, with others, the tube shift is from a high to a low position. When using a prism type of stereoscope (the standard type purchased by the United States Army for this purpose) it is necessary that the direction of film shift be the *same* as the direction of tube shift. If these directions be opposite, there is no way that the single film can be positioned without the right eye having to view the image belonging to the left eye and vice versa. The film shifter of the photoroentgen camera can be adjusted to provide for remote control of shifting either from a high to low or from a low to high position. This adjustment must be made in accordance with the particular design of the tube column. It is very important that this coordination be accomplished since in this type of work, ordinarily hundreds of stereoscopic images must be studied in a day and since the viewing of pseudo-stereoscopic images is so fatiguing.

255. OPAQUE MEDIA. Roentgenographic shadows occur only because tissues of different density and thickness absorb different quantities of roentgen rays. In many instances, the differential absorption is too little to be seen, or is covered over by the more or less dense shadows of other tissues. Again, the borders, more particularly the lumen of organs are indistinct because of lack of differential absorption. For example, the lumen of the stomach or of the intestines cannot by itself be readily visualized. In order to bring forth on the film or on the fluoroscopic screen, sufficient contrast to visualize outlines, materials are used whose absorption of radiations differ from the radiation absorption of tissues. Such materials are divided into two groups: those which are more dense and those which are less dense as compared with regional tissues. In the former group are barium sulphate, iodized oil, Diadrast, Pantopaque and others of one or another trade name; air and oxygen are examples of the second group. The administration of these materials is the responsibility of the roentgenologist. In some cases minor surgical procedures are involved. In others, the patient takes the materials orally in liquid form or by an enema tube. Since the technician may be required to administer the opaque media in the latter cases and since he must know what particular anatomical parts are to be roentgenographed, he should know in a general way wherein the various opaque materials are most frequently used. This information is given in the appendix II.

Figure 229. An improvised field stereoscope.

256. ISOLATION AND STERILE TECHNIQUE. The technician will often be called upon to perform roentgenography in the contagious disease (isolation) section of the hospital and, at other times, to perform roentgenography during the course of operative procedures. In both instances, he must be thoroughly familiar with and constantly observant of the techniques necessary to avoid contamination in the operating room, and being contaminated in the isolation ward. There are certain precautions common to both locations. In addition to the precautions to be observed, the difficulty of roentgenography and the necessity for speed in the case of the operating room make reexamination highly undesirable. In the operating room, the patient is usually anaesthetized and delay involves serious risk, so that unnecessary failures in roentgenography must be avoided. Before leaving the roentgenographic section, be certain that

a. The X-ray unit is in working order.

b. An ample number of loaded cassettes are available.

c. Proper identification of films can be made quickly.

d. Correct exposure factors are known for the part to be examined.

e. Wall outlets or extension cords are available at convenient locations.

In the event that roentgenography is to be performed in the operating room, it is best to ask for instructions as to the procedure to follow in performing the examination. Certain precautions will be common to most operating rooms. These are designed to avoid contamination of the operative field and are deter-

mined by the chief of the operating section. The technician will be required to wear a mask, cap, gown, and, in some instances, rubber gloves. After placing his unit in the proper position, the technician should inclose the cassette in a sterile sack. The cassette may then be placed in the operative field without danger of contamination. If it is desired that the technician not enter the operating zone, he may give instructions to one of the operative assistants as to how to position and hold the film. Unexposed films must be placed in a ray-proof location. After exposure, the films may be stacked with the unexposed films and they must be properly identified. The projections will vary with the operation performed. Most frequently, insertion of a metal stabilizing device for repair of fractures will be the occasion for roentgenography. In such instances, two views at right angles are to be obtained, if possible. Resourcefulness and ingenuity must be employed in the operating room, as projections will depend upon the position of the patient on the operating table. A safe rule in the operating room and in the isolation ward for the solution of problems of sterile technique is to ask for assistance and instruction and, at the same time, acquaint the attendants with your problems. Be grateful for any assistance and utilize it to the fullest advantage. Before closing the main switch of the X-ray unit, the anaesthetist should be consulted as to the safety of energizing the unit at that particular moment. This is necessary, because many of the anaesthetics being used are highly explosive, even minor arcing in the control may ignite their vapors. Where sufficient help is available, an assistant can be utilized to carry exposed films back to the darkroom for immediate processing. If the technician must leave the operating room he should disconnect his unit from the wall plug. On leaving the operating room, and in particular the isolation ward, the technician should carefully scrub his hands with soap and water. If the cassette is contaminated by fluid (blood, pus, etc.), it should be cleaned by wiping the fluid off, and the entire area carefully cleansed with a moist alcohol sponge. Always remember that these patients are ill, many from unknown causes, and serious risk follows careless exposure to coughing, sneezing, and contact with the patient unnecessarily. The technician is exposing himself to infection in direct ratio to his ignorance. When in doubt, reliable advice can usually be obtained from the person in charge of the isolation section.

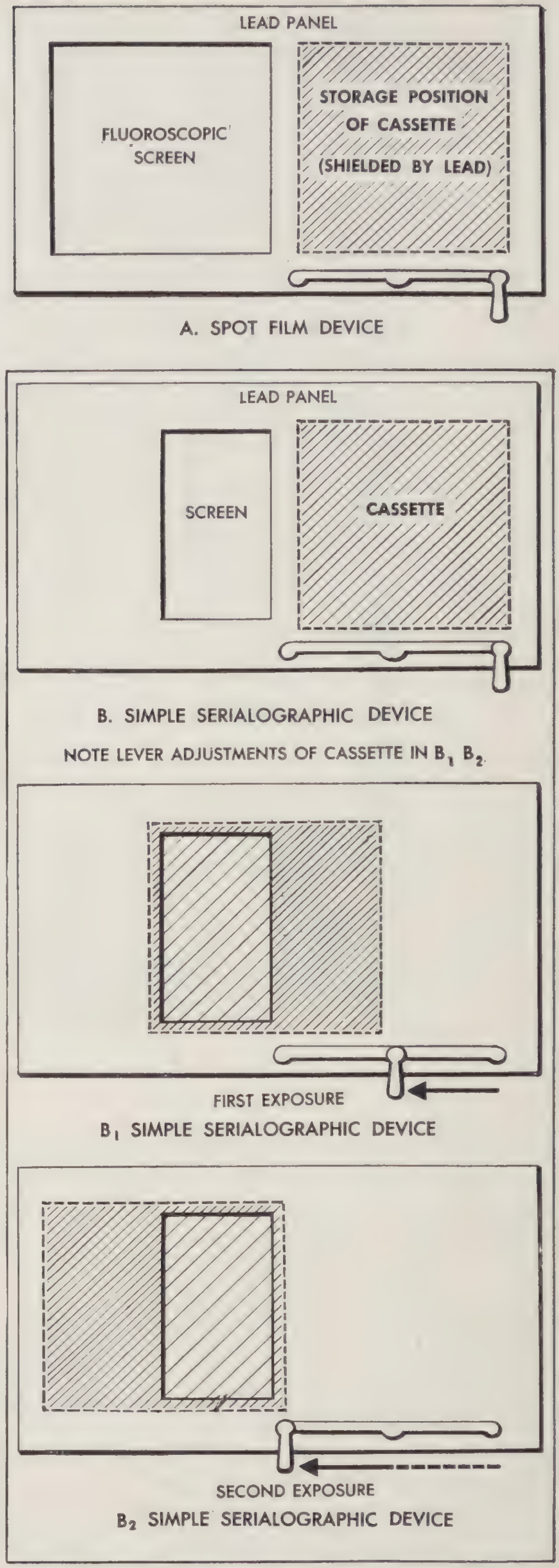


Figure 230. Spot-film roentgenography and serialography.

257. SPOT-FILM ROENTGENOGRAPHY AND SERIALOGRAPHY.

a. Spot-film roentgenography. Especially when studying gastro-intestinal physiology, during roentgenoscopy, it is oftentimes desirable to record onto a film, a particular finding. This finding may be transitory and capable of being visualized only by one or a few positions of the

patient. For such occasions, it is practical to accomplish roentgenography without changing the position of the patient and without delay. To provide for such expedient exposures, a spot-film attachment is practical. As shown in figure 230, the film (in cassette) is stored in a tunnel arrangement which is mounted on the patient's side of the fluoroscopic screen staging and in that position protected by lead. At the moment that the pertinent density comes into roentgenoscopic view, the roentgenoscopist releases the foot (or thumb) switch; he slides the film into position in front of the fluoroscopic screen as quickly as possible (that is, where it is unprotected by lead) and a roentgenographic exposure is accomplished. In this connection a rough estimate of exposure requirements might be that the X-ray tube be energized long enough to provide a distinct roentgenoscopic image on the screen (located on the examining side of the interposed cassette). Otherwise, readjustments of kilovoltage and milliamperage might be made on the controls. In the case of the field units, the exposure is made with the timer, rather than the foot switch. In such an instance, it must be emphasized that following the roentgenographic exposure, the controls must be readjusted to roentgenoscopic limits—a load of no more than 5 ma at 85 kvp or less. If this is not done *the filament or target of the x-ray tube may be destroyed.*

b. Serialography. This procedure basically consists of making a number of exposure onto a single film. It may be accomplished on the roentgenographic table utilizing a lead mask beneath the part and shifting the open portion of the mask so as to provide for a series of separate exposures onto the one film. However, the connotation of this term usually implies the same maneuvering as described for spot-film roentgenography. It may consist of exposing a series of roentgenograms, using a number of films whereby the entire area of each film is exposed, as described above or it might be accomplished by limiting the area of the projected image so that a number of exposures can be recorded onto a single film. For instance, as shown in figures 230-B, B_1 and B_2, the exposed area of the fluoroscopic screen may be confined to half (or even less) the area of the film; whereby, for the first exposure, the film is slid in front of the nonprotected portion of the fluoroscopic screen so that only one portion of it is exposed to the radiation. Following this exposure, it may be slid further so as to provide for exposures onto another portion of it, or it may be slid back into its storage position and subsequent exposures may be made as roentgenoscopic findings indicate their value. To provide for projecting the image to one and then another and possibly several areas of the film, there may be a lever or electrical spring device for shifting the film into the exposed "window" of its storage tunnel so that finally, two or more roentgenographic images are produced on the one film.

258. KYMOGRAPHY. Kymography is a roentgenographic technique for recording on a single film the displacement movements of any structure during the time of exposure. (See fig. 231.) The apparatus most commonly used consists of a stationary lead grid, $\frac{1}{16}$ inch thick, 16 inches wide, and 20 inches long. Multiple slits 0.4 mm wide and spaced either 12 or 18 mm apart are cut in the grid. The grid is mounted between the patient and film cassette, with slits of the grid either horizontal or vertical. During the exposure of the film to the roentgen rays, the cassette travels slowly at uniform speed and at right angles to the slits. The travel distance is slightly less than the distance between slits. This short distance prevents overlapping of slit exposures and provides unexposed strips on the film which divides the roentgenogram into frames. To record horizontal displacements, the slits are horizontal and the film moves vertically. A displacement parallel to the slits and in one direction only during the time of the exposure records on the film, a stairsteplike shadow. If the displacement alternates in direction, however, the recorded shadow has a wavy form. (See fig. 232). If there is movement of structure, or if the movement is at right angles to the slits, a straight line shadow is recorded. In the finished kymogram, each frame is composed of a series of exposures 0.4 mm wide, which together show the displacements of one point on the surface of the organ during the exposure period. Kymography is particularly valuable in distinguishing between pulsating and nonpulsating tumors in the study of certain types of heart diseases and occasionally the study of thoracic physiology, diaphragmatic movements, and gastro-intestinal contractions (using opaque media).

259. BODY-SECTION ROENTGENOGRAPHY. Body-section roentgenography (laminography, planigraphy, tomography) is a technique in which the tube and film move during the exposure in such a way that the roentgen shadow of one plane in the body remains stationary on the moving film while the roentgen shadows of all tissues above and below this plane have a progressive displacement on the film causing them to be blurred. The movement of the film and the tube may be horizontal, circular or spiral, depending upon the design of the apparatus. With any of these, a laminographic film of the chest may show the lung fields at the level of the esophagus, but without the superimposed bone shadows of the ribs. The simplest laminographic apparatus consists of a standard roentgenographic table, a movable cassette, and a movable tube head. The tube head and cassette are attached to the opposite ends of a vertical bar. The latter is pivoted at a selected point between the cassette and tube. The pivot point should be at the level of the body section to be examined. The patient is positioned on the table exactly as he would be for ordinary roent-

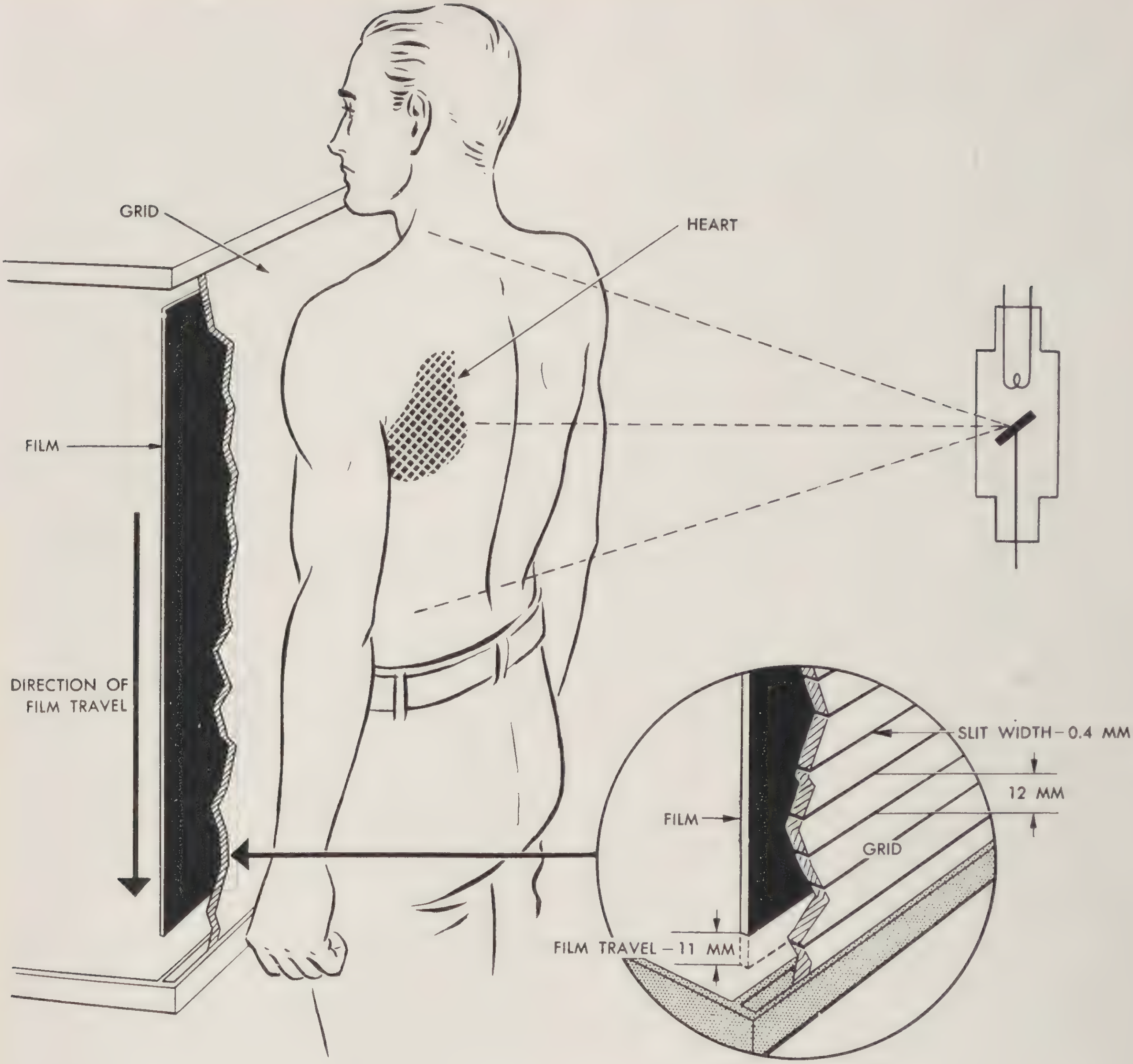


Figure 231. Kymography.

genography. Centering, measure of distances, etc., are accomplished with the tube directly above the part to be examined. All precautions of ordinary roentgenography are observed in laminography. As the tube travels in one direction, the cassette travels in the opposite direction and the exposure is made during the motion. (See fig. 233.) Thus, shadows concerned with the plane *A* (plane of pivot) fall on the same area of the film throughout the motion of film and tube; whereas, shadows of any other plane such as *B* will fall on different portions of the film surface with movement of the tube and film. The shadow of plane *A* will be sharp and relatively discernible, while the shadows of all other planes will be blurred and indistinct. By raising or lowering the position of the pivot, one or another level of the body may be visualized on the roentgenogram. A few elaborate laminographic machines of different designs have been manufactured. The additional cost and limited application appear to have thwarted extensive use of the principles. Body section roentgenography may be accomplished by the use of a simple auxiliary attachment adapted to the standard type of X-ray equipment. It may also be accomplished by special adaptation of the Army field X-ray table (Item 96145).

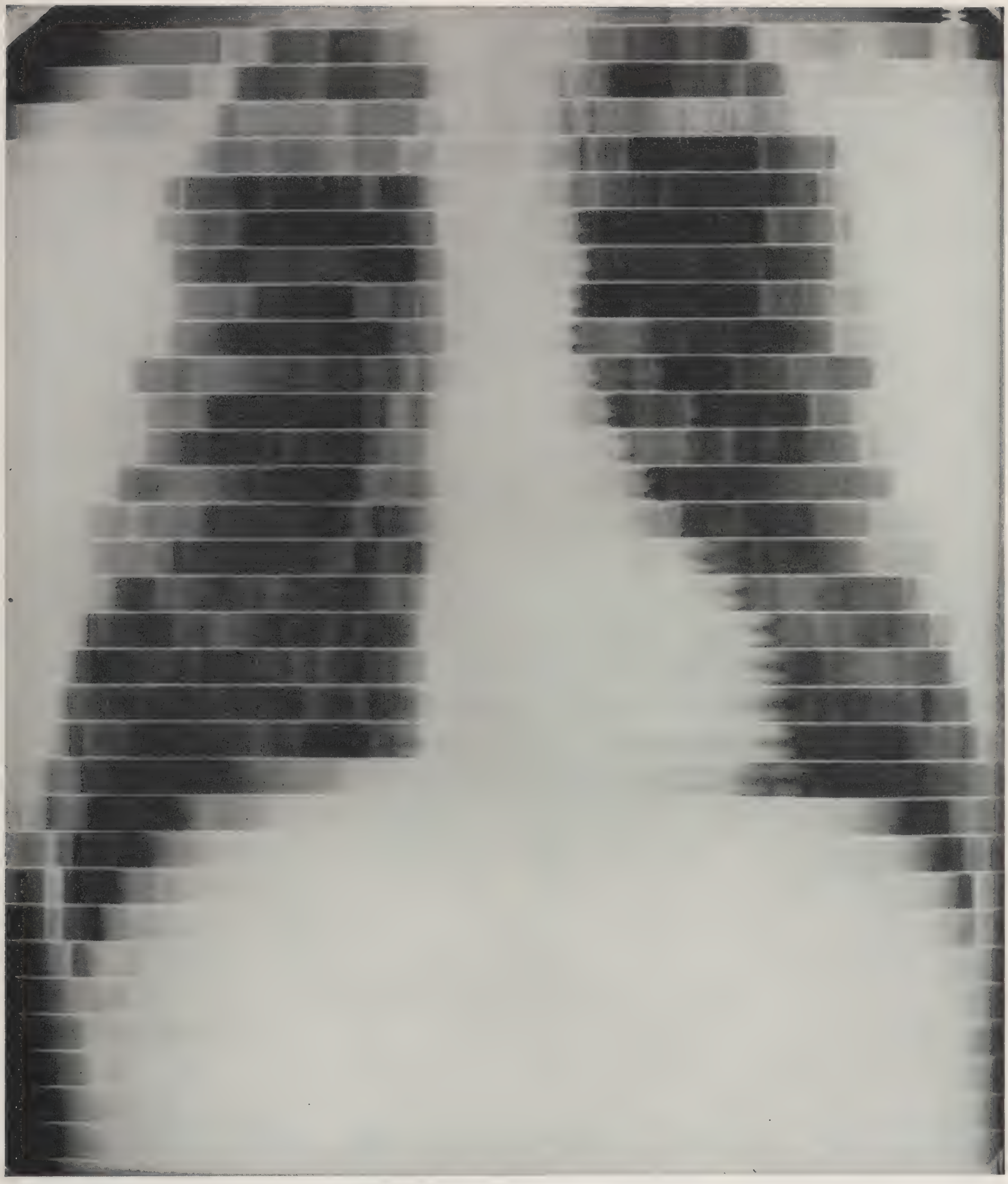


Figure 232. Roentgen kymogram.

260. PHOTOROENTGENOGRAPHY. Photoroentgenography (photofluorography) is the photography of fluorescent images which are normally seen on the fluoroscopic screen. The photoroentgen unit is essentially a camera assembly with a lens and film holder at one end and a fluorescent screen at the other. Back of the lens is the X-ray film holder whose size depends upon the lens system of the camera. A 4- by 5-inch single emulsion film is commonly used. Some designs accommodate 35-mm film. The fluorescent screen is 14- by 17-inch. This screen is not an ordinary fluoroscopic screen. The latter does not fluoresce bright enough to be photographed in the short time required in photoroentgenography. The "photoroentgen" screen is a high speed fluoroscopic screen. A photoroentgenogram is produced by carefully positioning the patient at the screen end of the camera. (See fig. 234.) The tube is centered and when energized, some of the rays penetrate the patient's body, projecting an image on the fluorescent screen. Thereafter, the fluorescent light rays are effective upon the film. A lead glass interposed between the screen and the lens serves to absorb X-rays while permitting transmission of the light rays. This image is recorded by the camera on the small film. (See par. 119.) The exposure time must be as short as possible (that is, $\frac{1}{2}$ sec. or less). Therefore, emphasis must be given to high kilovoltage, 80 to 100 kvp, utilizing milliamperages of 150 to 200. Best results have been obtained with special high capacity rotating anode tubes tolerating as much as 1,250,000 H. U. per hour. (See par. 51.) The film is processed as any conventional X-ray film. If stereoscopic films are desired, two equal exposures are made (on the same film) without moving the patient and with the tube in two different positions. For stereoscopic views, 4- by 10-inch films or two frames of the roll-type film are used. Automatic shifting of the tube and film are required for this procedure. The direction of film shift is arranged in accordance with the direction of the tube shift. (See par. 254*i*.) The purpose of photoroentgenography is to provide roentgenologists with films, equally as diagnostic as the conventional X-ray film, but easier to handle, easier to analyze and lower in cost as compared with the more standard films. The economic factor is important, particularly in mass roentgenological surveys of large groups of population. The cost per film of photoroentgenography is estimated to be about 10 percent of the cost of one 14- by 17-inch conventional size film. Another advantage of photoroentgenograms is the more simple and less bulky filing system required for them.

261. ROENTGENOSCOPY. a. General. Roentgenoscopy (fluoroscopy) permits observation of gross physiology—that physiology concerned with motion of the heart, diaphragm and alimentary tract, transport of contrast media through alimentary

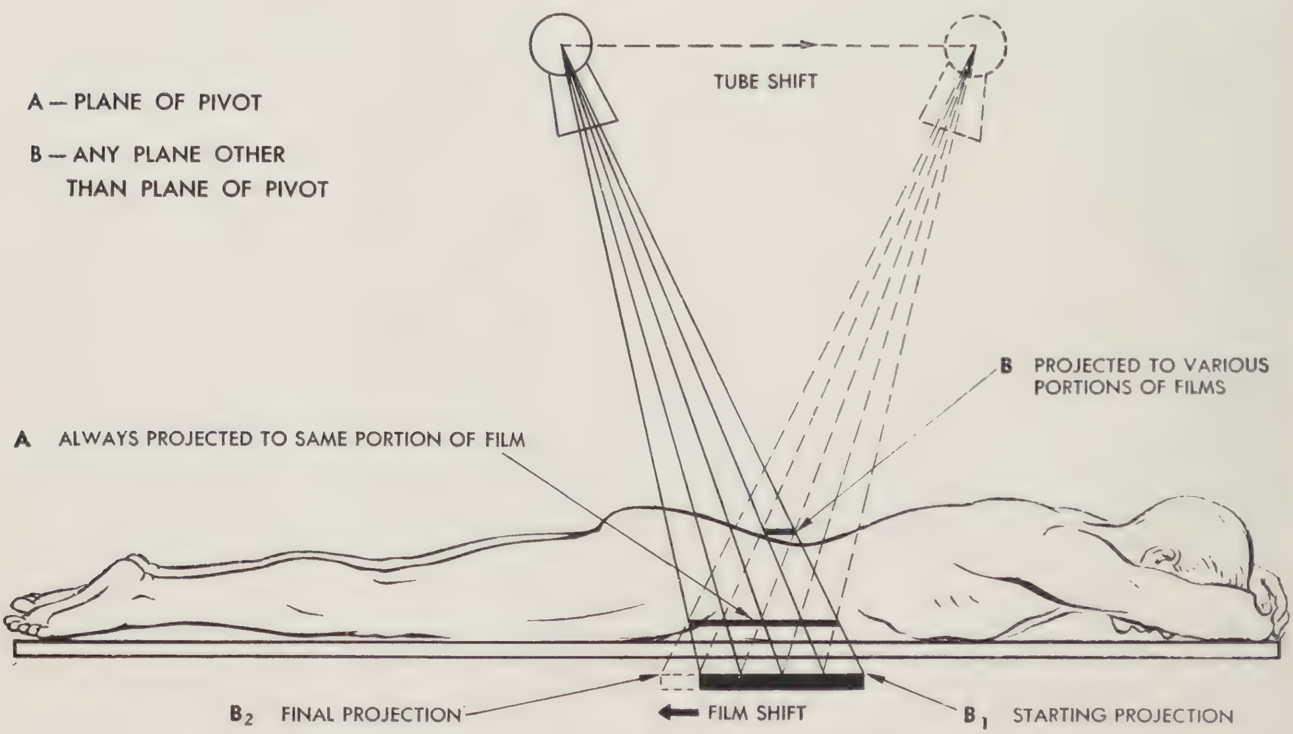


Figure 233. Body-section roentgenography.

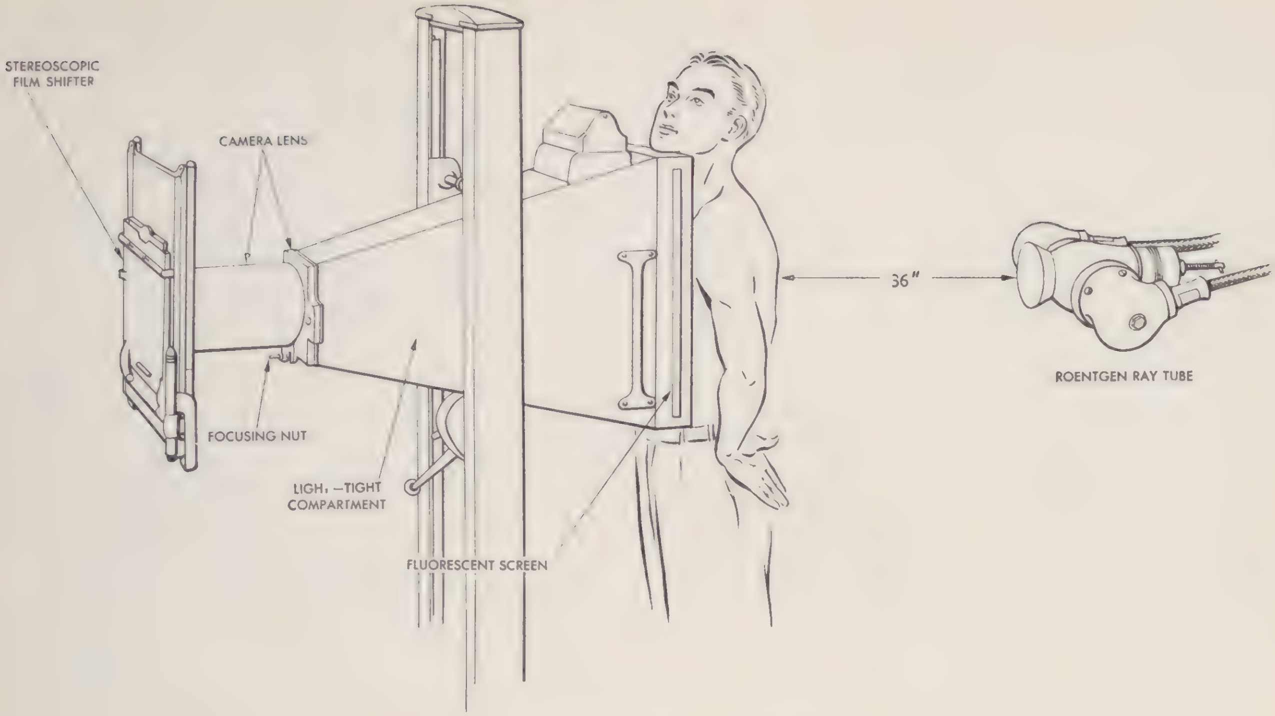


Figure 234. Photoroentgenography.

tract, etc.,—as well as of gross anatomy. The great value of roentgenoscopy lies in the opportunity for correlation of anatomy and physiology, normal or abnormal. Added value accrues through the ready alteration of a patient's position under roentgenoscopic observation; this serves to localize an abnormality in relationship to other structures and to establish which positions will be advantageous in roentgenography. Furthermore, such procedures as progressive filling of sinus tracts or the bronchial tree, by contrast medium, may be guided roentgenoscopically to insure that films will be exposed at the proper time (that is, with conditions neither of incomplete outlining nor overfilling).

b. Technical factors. Average machine settings for roentgenoscopy are 4 ma and 75 kvp. Some roentgenologists prefer average settings of 4 ma and kilovoltage values of 60 for extremities, 70 for chest, and 80 for abdomen. Positioning for roentgenoscopy depends on the part to be examined and the patient's condition. In general, part or all of chest, upper gastro-intestinal and bronchographic roentgenoscopic examinations are performed with the patient erect; colon and myelographic examinations require a horizontal position. As any examination progresses, need for changes in position can be met immediately and readily so that in any one examination the patient might be examined in the erect, horizontal and Trendelenburg positions in oblique, lateral, A-P, and P-A projections.

c. Protection. The necessity of protecting patient, roentgenologist and technicians from radiation hazards during roentgenoscopy cannot be overemphasized. The following precautions should be observed:

(1) The equivalent of 1.5-mm thickness of aluminum is required as a filter for the primary beam at the exit portal of the tube.

(2) Distance should be utilized as a protection: tube–skin distance should be kept at a maximum (no less than 12 inches) to protect the patient; technicians must remain away from the roentgenoscopic unit whenever their services are not required in the examination. The factor of decreased distance from the source of both primary and secondary rays accounts for the greater radiation to the examiner during horizontal, as opposed to vertical roentgenoscopy.

(3) Time (duration of exposure) should be kept at the minimum compatible with completion of the examination.

(4) Size of field—should be kept at a minimum to decrease the amount of the patient's tissue irradiated, and hence to decrease amount of secondary rays.

(5) Protective devices—lead gloves and apron should be worn by the roentgenologist and by the technician who must remain close to the unit to perform his work. Lead shields between the sources of radiation and the roentgenologist or technicians serve the same purpose; that is, to prevent rays from reaching these workers.

d. Dark adaptation. The greatest single limiting factor in roentgenoscopy's usefulness is the relatively poor vision of the human eye at low brightness levels. The brightness of the fluoroscopic screen during a gastro-intestinal examination is about $\frac{1}{30,000}$ the brightness of this page with average illumination for reading. For the eye to perceive such low brightness levels at all, dark adaptation is necessary. Dark adaptation, increasing the eyes' sensitivity to low brightness levels, is accomplished by excluding light from the eyes, usually by remaining in a totally dark room. Dark adaptation improves progressively even after a number of hours spent in darkness; practically, however, a compromise is struck between maximum dark adaptation and economical use of time, and 20 minutes in total darkness is considered to provide sufficient dark adaptation. The dark adapted eye's ability to resolve two contours that are close together and to distinguish differences in density increases with any increase in brightness. A better appreciation of the roentgenoscopic images will result if brightness is increased; increases in brightness, occasionally indicated in difficult diagnostic problems, may be attained by increasing ma to 10 and making several *very short* roentgenoscopic observations, this in addition to the routine roentgenoscopic examination. Once dark adaptation is acquired it must be carefully guarded, since even brief exposure to light will "wash out" dark adaptation. Therefore, the roentgenoscopic room should be light proof; any light leaks must be repaired. The entrance to the roentgenoscopic room must be light secure; if, for any reason, a door is to be opened (to admit a patient, etc.) those who are dark adapted should be warned by a knock on the door or a verbal admonition to "close your eyes" (the dark adapted workers should then close their eyes, turn away from the entrance and probably cover their eyes with their hands). Lights outside the entrance to the roentgenoscopic room should be dim and shielded so their direct beam cannot shine into the roentgenoscopic room. The primary X-ray beam should be confined to areas covering the patient; thus counteracting intense illumination of the screen because of direct exposure of it (that is, without interposed part). A dim red light (deep red light is least effective in "washing out" dark adaptation) is the only illumination permitted in the roentgenoscopic room between examinations or during adjustments of patient or unit.

e. Technique of examination. Examination techniques vary, not only for different types of examination but from examiner to examiner. Each roentgenologist develops his own routine procedure for a given examination. All these methods require teamwork between the examiner and the technicians, hence, each must be familiar with the routine to expedite the examinations. Chest roentgenoscopy is performed with the patient upright, if his condition permits. It consists basically of examining the various portions of the chest in various projections and phases of respiration; a swallow of barium paste is used to outline the esophagus' position. Upper gastro-intestinal roentgenoscopy is performed with the patient upright at first; later, horizontal. Chest roentgenoscopy usually precedes the gastro-intestinal examination. Colon studies require the patient to be in a horizontal position. That time may be wasted if teamwork is lacking is at once evident. The technician must know when the roentgenologist wants a glass of barium mixture handed to the patient, when the empty glass is to be taken from the patient, and when the table is to be tilted to a different position. The roentgenologist, in turn, seeks to guide the technician by adhering to a routine in his examination and in his remarks to guide the patient; the technician knows, for example, that when the examiner tells the patient, "Face me now," that the next step will be to hand the patient the glass of contrast medium. Regardless of the type of examination being done, the patient's peace of mind must be assured. Personnel in the roentgenoscopic room must realize that the patient is not dark-adapted; when he steps into the "dark" room, he requires guidance. He should be told that "the floor is level" or any other statement to allay his worry and fear of the examination. All efforts at kindly, reassuring management of the patient in the roentgenoscopic room will be well repaid by the patient's voluntary cooperation and, more important, by the cooperative calm of his involuntary actions (such as gastro-intestinal movements).

f. Routine scheduling. A certain definite period should be set aside for roentgenoscopic study of all cases scheduled for the day. Intermittent activities are condemned because they lead to a wastage of time or inaccuracy of examination and unnecessarily prolonged exposure of the patient. Injustice to the patient may result because of: inadequate examination due to inability to visualize all that should be seen and unnecessary radiation exposure due to attempts to compensate for lack of dark adaptation. Not infrequently, these shortcomings are not realized by referring doctors when making selfish demands for unscheduled examinations. Only the exceptional individual may insist upon adequate preparation by way of dark adaptation, preparing for periods of 20 minutes or longer for each 5 or 10 minute study.

CHAPTER 12

FOREIGN BODY LOCALIZATION

SECTION I. ROENTGENOSCOPIC LOCALIZATION

262. GENERAL. Both X-ray field tables have been designed to provide for a rapid roentgenoscopic method of localization of ray opaque bodies. The method is based upon triangulation principles, utilizing large dimensional relations. This particular method has been selected because of several favorable features:

a. Simplicity of the auxiliary parts required.

b. Ease of making the alignments. Instead of wires or diaphragm cut-off to be visualized through the density of an overlying part, clearly discernible intersecting lines on the fluoroscopic screen are used.

c. Short time requirement for roentgenoscopic localization of any one foreign body—less than 1 minute.

d. Minimal ray exposure imposed upon the patient —no greater than 150 milliampere-seconds with a focal-skin distance of 12 inches or more (with negligible secondary radiation directed toward the examiner and assistants).

e. Accuracy of localization. This method is limited only by technical discrepancies on the part of the operator provided the focal-screen distance and reading level are properly adjusted before making the calculations. (See par. 264.)

f. Provision for positioning of the fluoroscopic screen either in contact with the skin surface or at a distance above it, thereby permitting clearance for manipulation.

g. Convenience in marking of the skin surface. This can be accomplished with true alignment relations but without resorting to the application of the skin marker through an opening of the fluoroscopic screen.

263. WORKING PARTS. a. To provide for this method of localization, only two auxiliary parts are required. Neither of these is easily detachable nor small enough to be easily lost. These parts are:

(1) Combination depth scale and skin marker which should be mounted on the supporting arm of the fluoroscopic screen.

(2) Localization scale and its adjustable pointer which are attached to the horizontal carriage.

b. The focal spot of the X-ray tube is located at a distance of 66 centimeters beneath the center of the fluoroscopic screen. There are inscribed upon the fluoroscopic screen three sets of intersecting lines. One of these sets is located in the center of the screen; another, 11 centimeters beyond it toward one end of the screen; while the third is located 11 centimeters in the opposite direction from the middle. Thus the spacing between the outer sets of intersecting lines is 22 centimeters or one-third of the focal-screen distance (except for minor correctible variations in the latter).

264. PRELIMINARY TESTINGS. a. General. With either design of table unit, localizations are accomplished with the setup as for horizontal roentgenoscopy. The **C**-shaped member must be adjusted so that the X-ray tube is positioned below the level for the litter and patient and the fluoroscopic screen above this level with adequate clearance for the patient. The adjustment should be such that the "principal ray" will be perpendicular to the patient. If there be a wafer grid on the cassette lifting device (located on the horizontal carriage, with most of the tables), this grid should be removed and either set to one side or slid into the channel beneath the roentgenoscopic screen (in which case, it is important that the "tube side" of the grid be facing toward the tube). (See par. 109.) Prior to lifting the patient onto the table, it is essential that there be accuracy of focal-screen distance and that the reading level concerned with the depth scale be properly adjusted.

b. Checking of focal-screen distance. With most of the units, there is provided on the horizontal arm support for the fluoroscopic screen a clamp (fig. 235) concerned with adjustment of the screen to accurate distance (66 centimeters) from the focal spot of the X-ray tube. In order to adjust the proper level for the fluoroscopic screen, the table units having this adjustable clamp are also provided with a calibration gauge. This gauge is of metal **U**-shaped construction, having either of two designs: two pins (Item 96215) or a hook (Item 96145) incorporated into the extremity of each of its two vertical arms and two circular slots cut into its connecting horizontal arm. This **U**-shaped gauge should be suspended from the fluoroscopic screen, hanging from it by support of the hook arms or pins *closest* to the free ends. (In the case of Item No. 96215 the positioning of the **U**-shaped gauge must be over the base frame of the fluoroscopic hood.) The gauge should be positioned so that the arm having the circular slots is aligned and directly below the three intersections

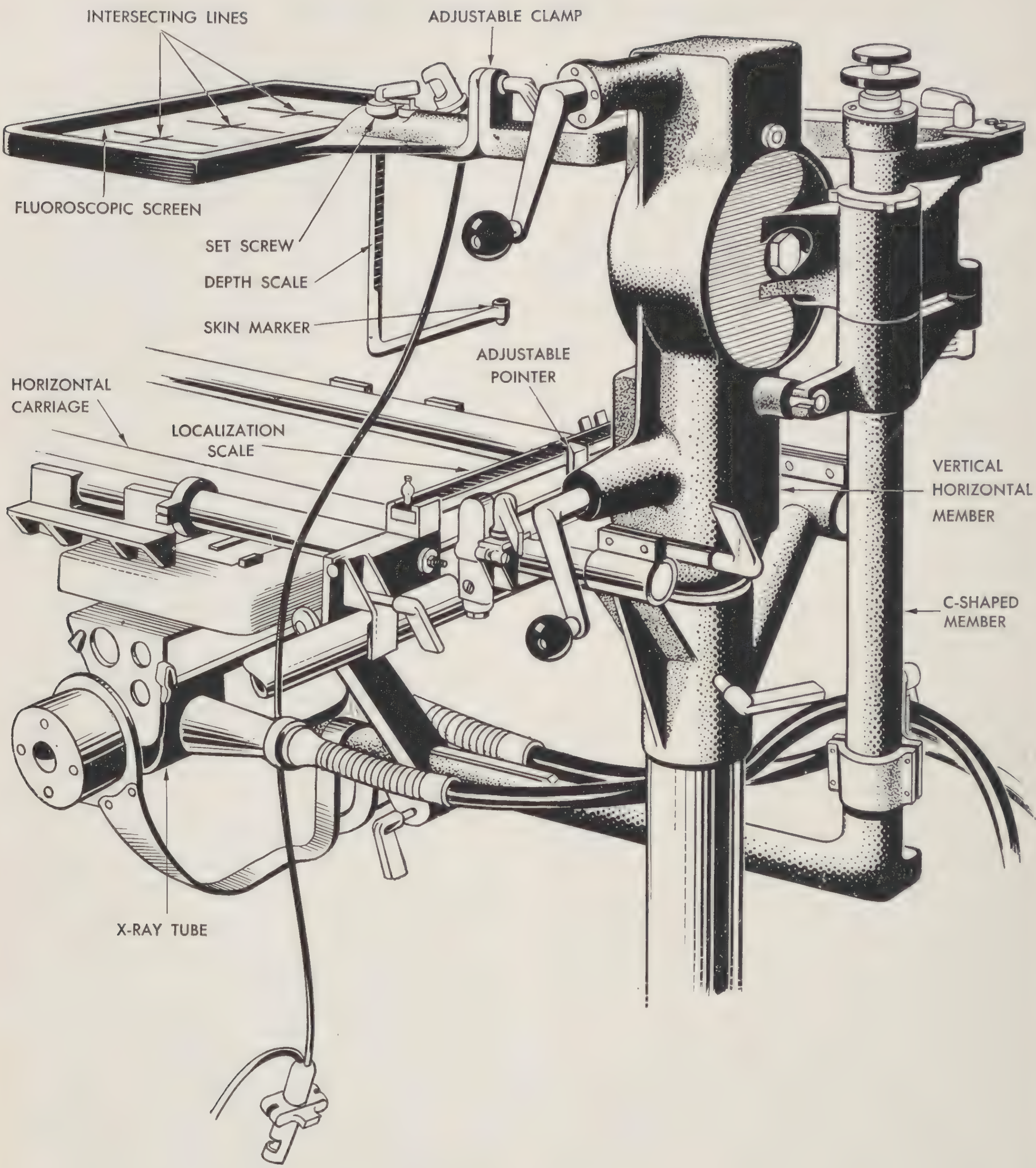


Figure 235. C-shaped member of field table—Item 96145.

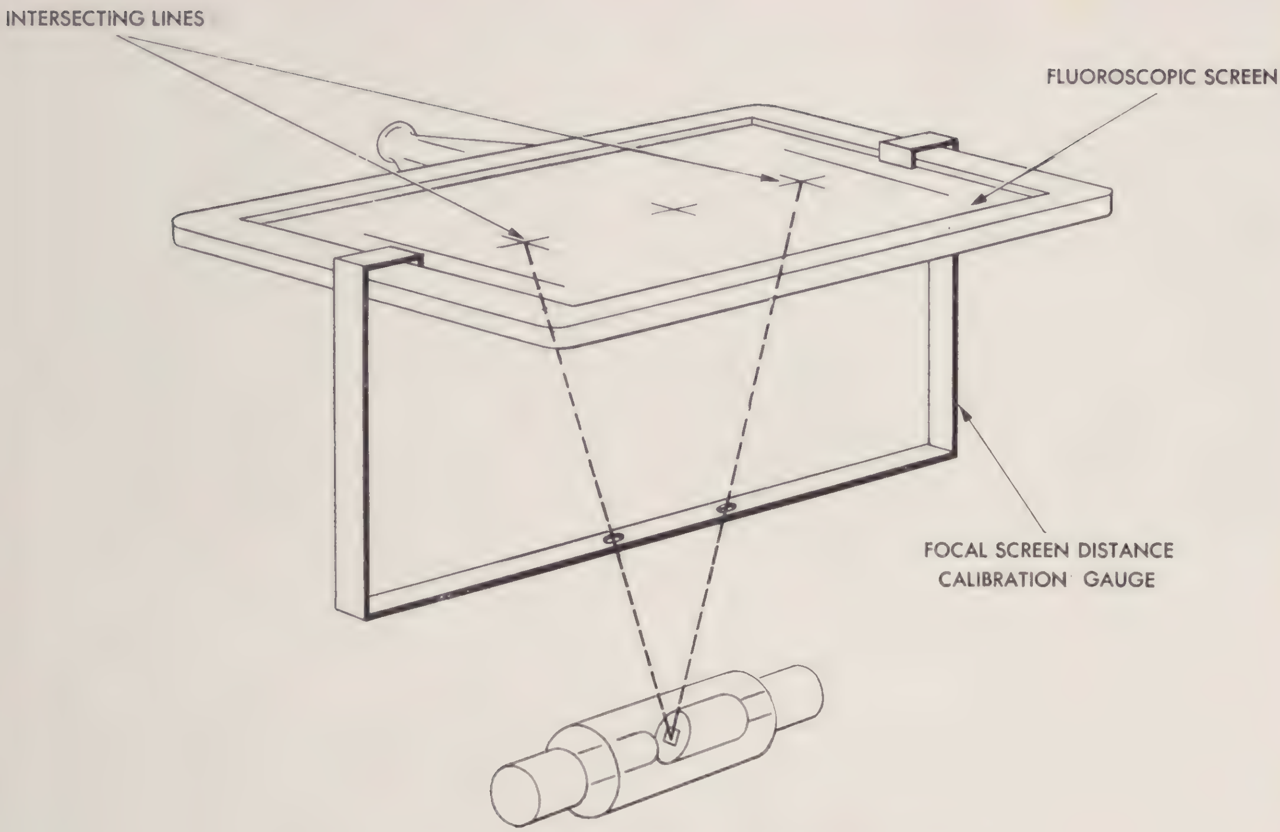


Figure 236. Application of focal-screen gauge (Item 96145).

of the intersecting lines of the fluoroscopic screen. After energization of the X-ray machine, using factors such as 50 kvp and 3 ma, the gauge should be positioned so that the projected image of the cross line of one of the circular slots coincides with one of the outer intersecting lines of the screen. If, then, the projected image of the cross line of the other circular slot does not coincide with the opposite outer intersecting line of the screen, the adjustable clamp of the horizontal support of the screen should be loosened and the fluoroscopic screen then raised or lowered until the projected images of the cross lines of the two slots are exactly superimposed upon the intersecting lines. (See fig. 236.) The screen clamp should then be tightened and a rechecking should be accomplished in order to make certain that the alignments are still correct.

c. Adjustment of depth marker, Item No. 96215. There will be found two sets of supporting pins, on the free arm of the **U**-shaped gauge for this item. After accomplishing accurate positioning of the fluoroscopic screen with respect to the focal spot of the X-ray tube, as described above, this gauge might be used for properly adjusting the marker tip. The gauge should be suspended from the fluoroscopic screen by means of the two pins *farthest* from the open ends of the "U" (again having the suspension from the base frame of the fluoroscopic hood). The depth marker should then be rotated into position and lowered until its marking tip rests upon the horizontal arm of the gauge. When in contact at this point, the vertical scale of the depth marker should read 14.7 cms at its reading level. If it reads more or less, adjustment should be made of the set screw for the well of the marking pad. After accomplishing the proper adjustment providing for an exact reading of 14.7 cms on the vertical scale of the depth marker when the marking well is resting upon the horizontal arm of the gauge, this screw fixation should be made secure.

d. Reading level adjustments. Regardless of these adjustments, preliminary checking should be made as to proper positionings for the reading level concerned with the vertical scale of the depth marker. This adjustable feature was provided for the purpose of more definitely insuring accuracy, regardless of corrugations which might occur in the bakelite support of the fluoroscopic screen, or to counteract errors which might occur because of parallax due to the position of the examiner. Furthermore, in the case of the earlier constructed tables, there was no provision for vertical adjustment of the fluoroscopic screen and with such tables, compensation for errors in the focal-screen distance

(that is, variations from 66 cms) had to be accomplished by this means, alone. As the equipment is shipped from the factory, the reading level is positioned properly in relation to the *average* X-ray tube assembly. However, in order to be certain that this level has not shifted, or that an abnormal position of focal spot be not responsible for appreciable variation in alignment values, preliminary testing should be conducted in the following manner:

(1) Place a board across the litter (table top) to provide for a rigid surface (comparable to the patient). On this board, 3 or 4 cms beneath the fluoroscopic screen, place the depth phantom (to be found in the packing chest of the table unit) in position so that the lead letters are on planes which respectively represent their distances below the top surface of the phantom as shown in figure 237.

(2) Align one conspicuous point of the number "12" to either of the two outer intersecting lines of the fluoroscopic screen.

(3) Adjust the pointer to the value on the localization scale so that it points to "12." This adjustment must be made to the "12" on the end of the localization scale coinciding with that of the intersecting lines selected (Item 96145) or to the "12" of the semicircular scale (Item 96215) having the same code color as the intersecting lines concerned on the screen.

(4) Shift the tube and the screen in the opposite direction until the very same point of the lead number "12" of the depth phantom is aligned to the opposite outer intersecting line on the screen.

(5) Read the new value indicated on the localization scale.

(6) Shift the fluoroscopic screen and X-ray tube to a position for alignment of the lead number "12" (of the phantom) to the middle set of intersecting lines on the screen. Superimpose the skin marker into this alignment and lower the depth scale until the skin marker rests upon the top surface of the depth phantom. Read the value indicated on the depth scale—the indicated depth of the top of the phantom (substituting for the skin surface) beneath the fluoroscopic screen.

(7) In case the depth scale value indicated in (6) above, does not coincide with the value indicated in (5) above, with Item 96145, release the setscrew used with the reading level (fig. 235) and readjust the reading level to the value indicated in step (5) above; in the case of Item 96215, readjust the marking well to raise or lower the depth scale as required. Once having set this reading level in this manner, it should not be necessary to readjust it, unless there are extreme changes in weather conditions and provided the X-ray tube is not changed. Setscrews should be securely clamped for fixation of the reading level. Should there be extreme changes in weather conditions so that the bakelite support of the fluoroscopic screen becomes buckled or changes from a buckled state to that of a true plane, a recheck as above described should be accomplished. Such changes in the level of the fluoroscopic screen are likely to alter the degree of parallax and, unless the reading level is readjusted, errors to the extent of several millimeters may be incurred. It is important that several testings be conducted in order to establish the correct position for this reading level. It is recommended that these testings be made with the use of the "3" centimeter as well as with the use of the "12" centimeter phantom objects and that these be checked for various positions of the fluoroscopic screen (as obtained by shifting the position of the fluoroscopic screen and the tube—that is, the **C**-shaped member in its entirety, in the vertical plane). This preliminary testing procedure is the opposite of the actual procedure concerned with localization for foreign bodies.

265. LOCALIZATION PROCEDURE, USING ITEM NO. 96145. The procedure is as follows:

a. Check fixation locks on **C**-shaped member; secure alignment of focal spot to center of fluoroscopic screen.

b. Align a prominence on foreign body to intersection of middle set of intersecting lines. (Fig. 238.)

c. Dampen skin marker pad with tincture of iodine, gentian violet, or ink and adjust it to this alignment (foreign body and intersection of middle set of intersecting lines); lower skin marker pad until it *rests* on the skin (or top of the depth phantom), thereby marking it.

d. Read distance between fluoroscopic screen and skin (or top of the depth phantom) by way of scale on depth marker. Raise and rotate skin marker out of screen field.

e. Shift tube and fluoroscopic screen to align the same prominence of the foreign body, as considered in step (b) above, to the intersection of either of the outer sets of intersecting lines. (See fig. 238B.)

f. Slide localization scale and adjust pointer to the centimeter value coinciding with the centimeter distance between the fluoroscopic screen and the skin as measured in step (d) above—this is the arbitrary zero. Clamp cuff for fixation of pointer to side rail of table.

g. Slide X-ray tube and fluoroscopic screen in direction opposite to that used in step (e) above, until the same prominence on the foreign body becomes aligned to the intersection of the opposite outer set of interesecting lines. (See fig. 238C.)

h. Read on localization scale the depth of foreign body beneath the skin (or top surface of depth phantom).

i. Identification of each spotting, together with record of the depth position of the foreign body beneath such, should be written onto the skin surface of the patient or upon any dressings as described in paragraph 270.

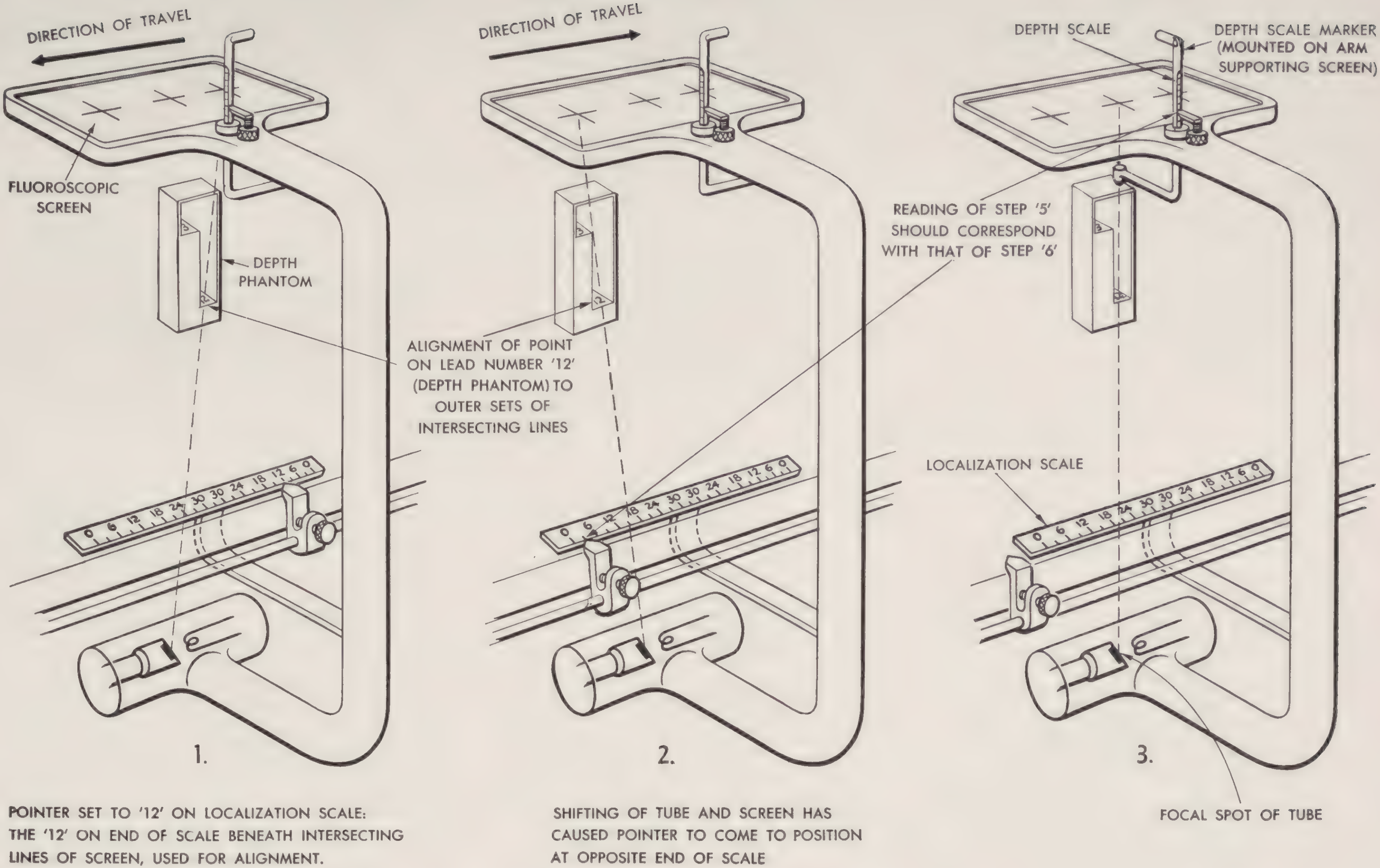


Figure 237. Positioning of reading level for depth scale—Item 96145.

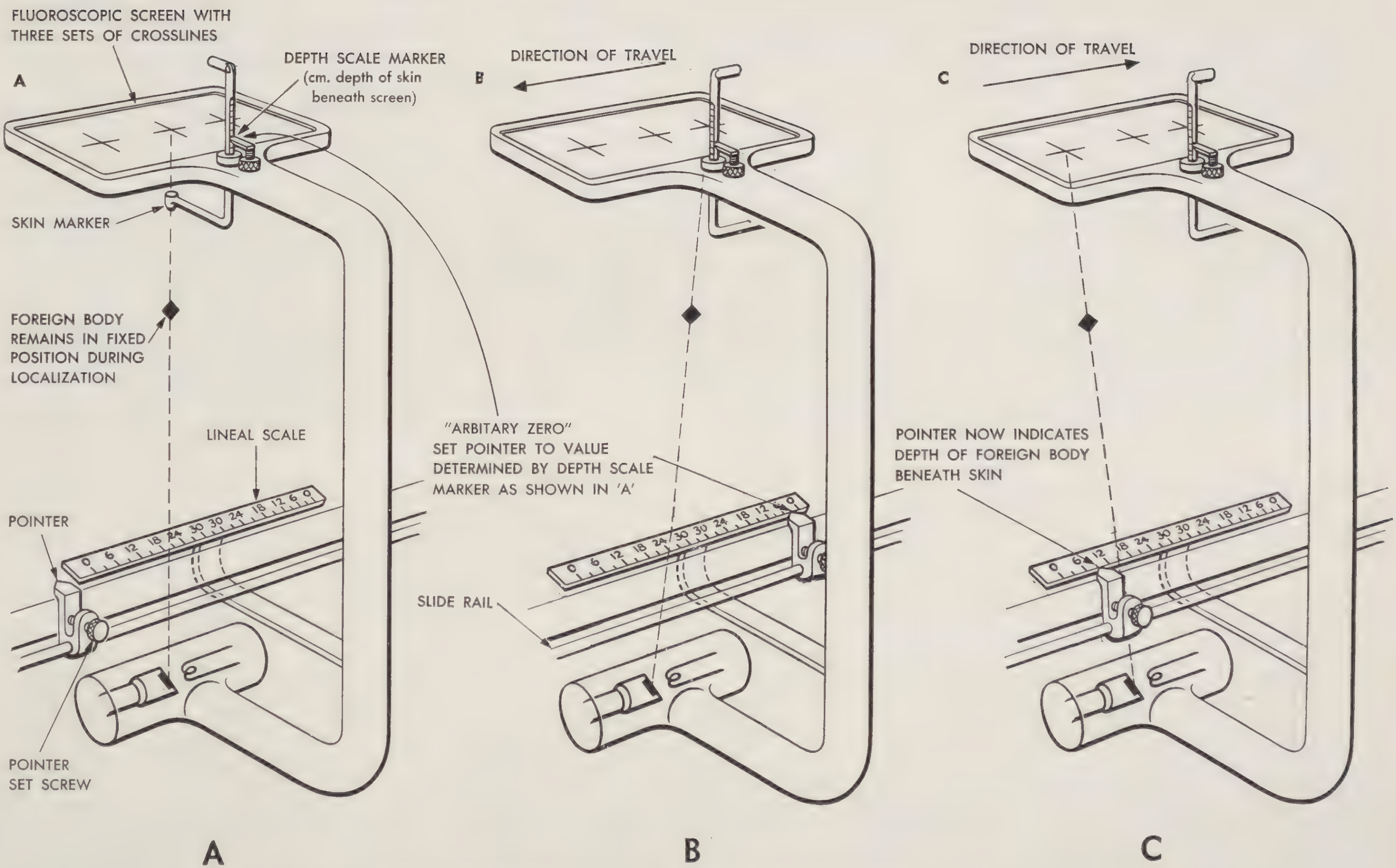


Figure 238. Procedure diagram—foreign body localization—Item 96145.

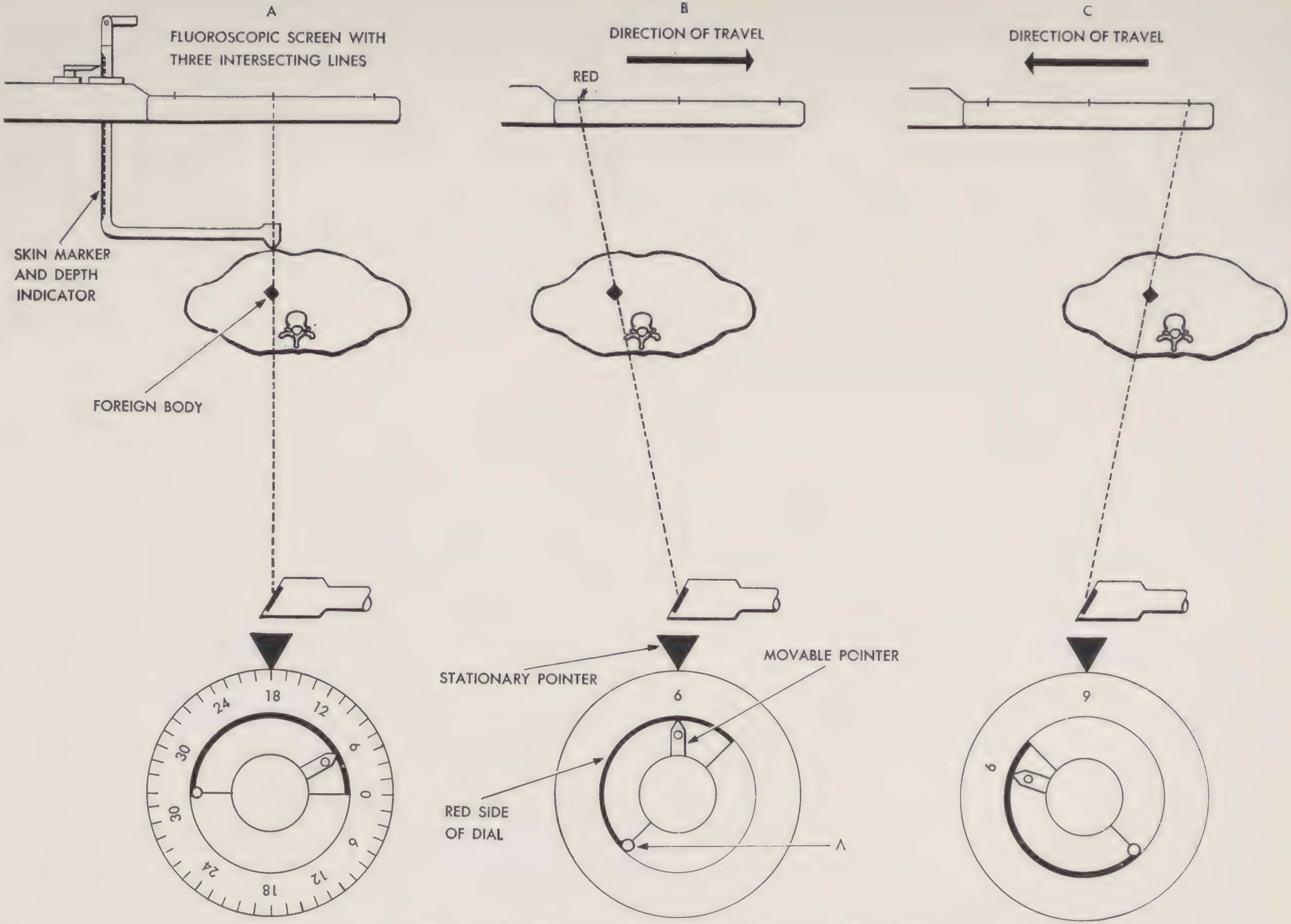


Figure 239. Procedure diagram—foreign body localization—Item 96215.

266. LOCALIZATION PROCEDURE, USING ITEM NO. 96215. **a.** The procedure is identical with that described above, though the distance between the screen and skin as indicated on the scale of the depth marker (par. 265d) is not transferred to a linear horizontal scale as diagrammed in figure 238; instead, with this unit, it is possible to adjust a pointer to a value on the localization dial, which coincides with the skin-screen distance. This setting can be accomplished immediately after reading the skin-screen distance. Following the alignment of the foreign body to the intersection of one of the outer sets of crosslines on the screen, the localization dial is turned so that the large pointer (still pointing to the skin-screen distance) is set to the pointer fixed on the outer periphery. (See fig. 239.) This setting must be made to the numerical values having the same color as identifying the outer intersecting lines selected for the first localization alignment (that is, red or black). Thereafter, the X-ray tube and fluoroscopic screen are shifted (fig. 239B) as described in (par. 265e and g) and the final localization of the foreign body is indicated on the dial scale. This localization must be indicated by the *fixed* pointer to a value on the disk scale having color *other* than that of the scale to which the pointer was first set; otherwise, a rechecking of the steps described in paragraph 265 should be accomplished.

b. As mentioned in paragraph 265, each spotting should be identified and the depth position of the foreign body, recorded onto the skin surface of the patient or overlying dressings.

267. GEOMETRIC ANALYSIS OF METHOD. Figures 240 to 247 provide geometric reasoning concerned with the roentgenoscopic localization.

268. PRECAUTIONARY MEASURES. **a.** Most important is the matter of proper positioning of the reading level for the depth scale (par. 264).

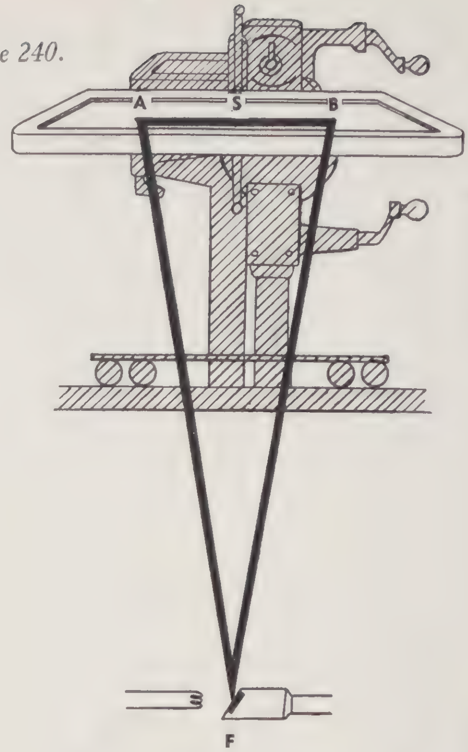
b. Special attention must be given to the vertical column of the **C**-shaped member (Item 96145). Two clamps are provided for firm fixation of this member in order to avoid any change in relations during the shiftings. These clamps should be released before making any vertical adjustments of the **C**-shaped member or before rotating it.

c. To accomplish the shiftings of the X-ray tube and fluoroscopic screen, pressure should be exerted not upon the screen itself nor its horizontal arm support, but instead, upon the fixed supporting column. (See fig. 235.)

d. It is important that the same landmark, the same point of the foreign body, be used for each phase of the alignments.

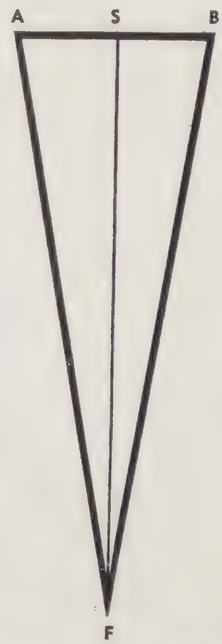
e. As nearly perpendicular viewing as possible should be performed by the examiner in making the alignments and also in reading the scales in setting the adjustable pointer.

Figure 240.



△AFB IS A FIXED RELATIONSHIP FOR ANY ALIGNMENT OF A FOREIGN BODY

Figure 241.



LET:

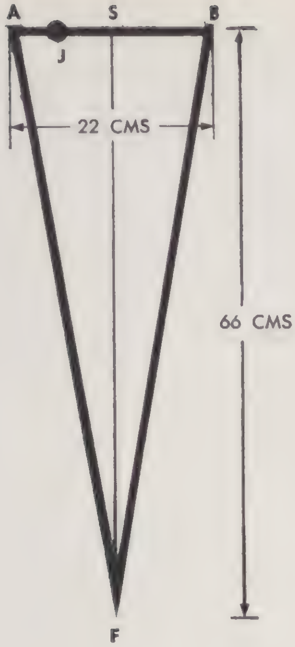
A, B AND S REPRESENT CROSS LINES ON SCREEN, AS = SB

F REPRESENTS FOCAL SPOT

THEN:

AF AND BF REPRESENT THE BOUNDARIES OF INCIDENT RAYS FROM F TO A AND F TO B

Figure 242.



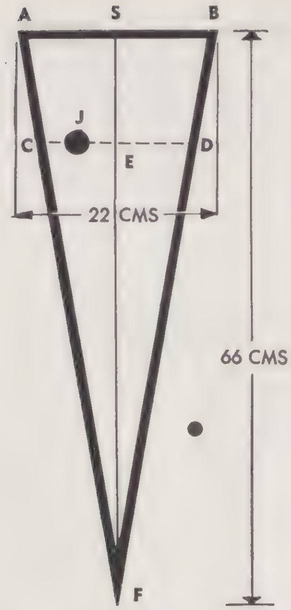
ASSUME:

A FOREIGN BODY J AT ANY POINT
ON PLANE OF SCREEN BETWEEN A AND B

THEN:

FOR ALIGNMENT OF FOREIGN BODY TO ONE
AND THEN THE OTHER OUTER CROSS LINES • • •
△AFB MUST SHIFT A DISTANCE AB, EQUAL TO 22 CMS

Figure 244.



ASSUME:

FOREIGN BODY J AT
ANY OTHER LEVEL

THEN:

IN ALIGNING, △AFB IS SHIFTED
TO PLACE J AT C (ALIGN TO AF)
AND AT D (ALIGN TO BF) CD∥AB

AND △CFD∽△AFB

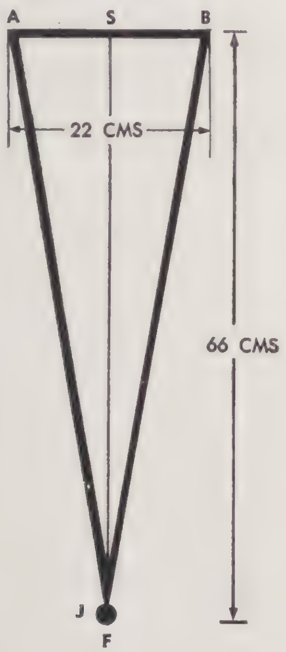
$FS : FE :: AB : CD$

OR $66 : FE :: 22 : CD$

$66CD = 22FE$

$CD = \frac{FE}{3}$ OR $FE = 3CD$

Figure 243.



ASSUME:

FOREIGN BODY J AT POINT F
(SF = 66 CMS)

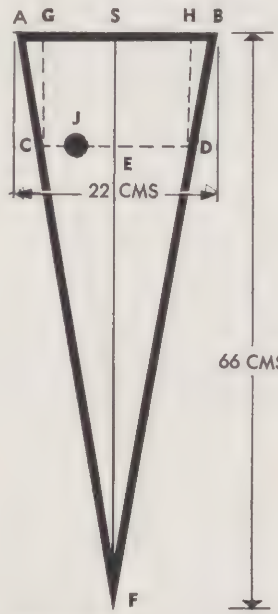
THEN:

NO MOVEMENT OF △AFB IS
NECESSARY FOR ALIGNMENT

THEREFORE:

FOR MAXIMUM
THEORETICAL SCREEN—
FOREIGN BODY DISTANCE
(66 CMS), THE SHIFT FOR
ALIGNMENT IS ZERO

Figure 245.



CONSTRUCT:

CG AND DH ⊥ TO AB

THEN: $FE = 3CD = 3GH$

$AB = (AG + GH + HB)$

$FS = FE + ES$

$FS = 3AB$

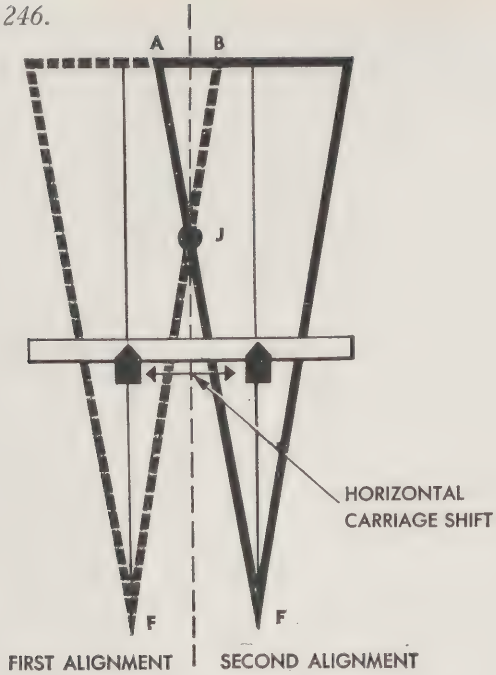
$FE + ES = 3(AG + GH + HB)$

SUBTRACT: $FE = 3GH$

$\therefore ES = 3(AG + HB)$

OR, SCREEN TO FOREIGN
BODY DEPTH =
3(22 CMS—CARRIAGE SHIFT)

Figure 246.



A SCALE AND POINTER ON MACHINE MEASURES "CARRIAGE SHIFT" DURING ALIGNMENT OF BODY J

Figure 247.

IN ACTUAL PRACTICE IT IS THE OBJECT—SKIN DEPTH (EK) THAT IS OF PRIMARY VALUE

$$EK = ES - KS$$

KS IS DETERMINED BY A DIRECT READING OF THE DEPTH SCALE MARKER.

$$ES = 3(AG+HB)$$

$$EK = 3(AG+HB) - KS$$

269. THE BIPLANE MARKER. a. General. It is usually of value to the surgeon to have spottings as to planes at right angles to one another, indicating the position of the foreign body. For this purpose, there has been provided a biplane marker, Item No. 96191. This device, furthermore, serves to indicate the position of the patient at the time of the localization and thereby, in conjunction with the reorientating device, it serves to reestablish at the operating table, the anatomical relations as they pertained at the time of localization.

b. Working parts. The biplane marker (fig. 248) consists of the following parts:

1. VERTICAL SLIDE.
   - (A) Contact rails
   - (B) Two Centimeter Scales
   - (C) Slide Lock Lever
   - (D) Pilot Light Cable Lead
   - (E) Marker Housing
   - (F) Release Catch—for Marker Housing
   - (G) Felt Marker
   - (H) Lucite Tip
   - (I) Marker Plunger
   - (J) Vertical Slide Release Catch
2. HORIZONTAL SLIDE WITH VERTICAL SLIDE HOUSING AND MEASURING TAPE CLIP
   - (A) Vertical Slide Housing
   - (B) Horizontal Slide Arm
   - (C) Tape Clip
   - (D) Tape Clip Lever
   - (E) Tape Clip Catch
3. HORIZONTAL SLIDE HOUSING AND YOKE
   - (A) Horizontal Slide Rectangular Openings
   - (B) Centimeter Tapes
   - (C) Housing Metal End Plates
   - (D) Pilot Light Cable Lead
   - (E) Horizontal Yoke Pin
   - (F) Yoke Thumb Screws
   - (G) Spirit Levels
4. SCREEN CLAMP
   - (A) Adjustable Block
   - (B) Horizontal Slide Arm
   - (C) Stationary Block
   - (D) Yoke Lock Handle
5. PILOT LIGHT CONNECTING CABLES
   - (A) 6-Volt Control Connection
   - (B) 6-Volt Field Table Supply
   - (C) Biplane "on-off" Switch
   - (D) Horizontal Light Connection
   - (E) Vertical Light Connection

All letters, A, B, etc., refer to various sub parts of the main unit. Main parts are outlined as 1, 2, 3, etc.

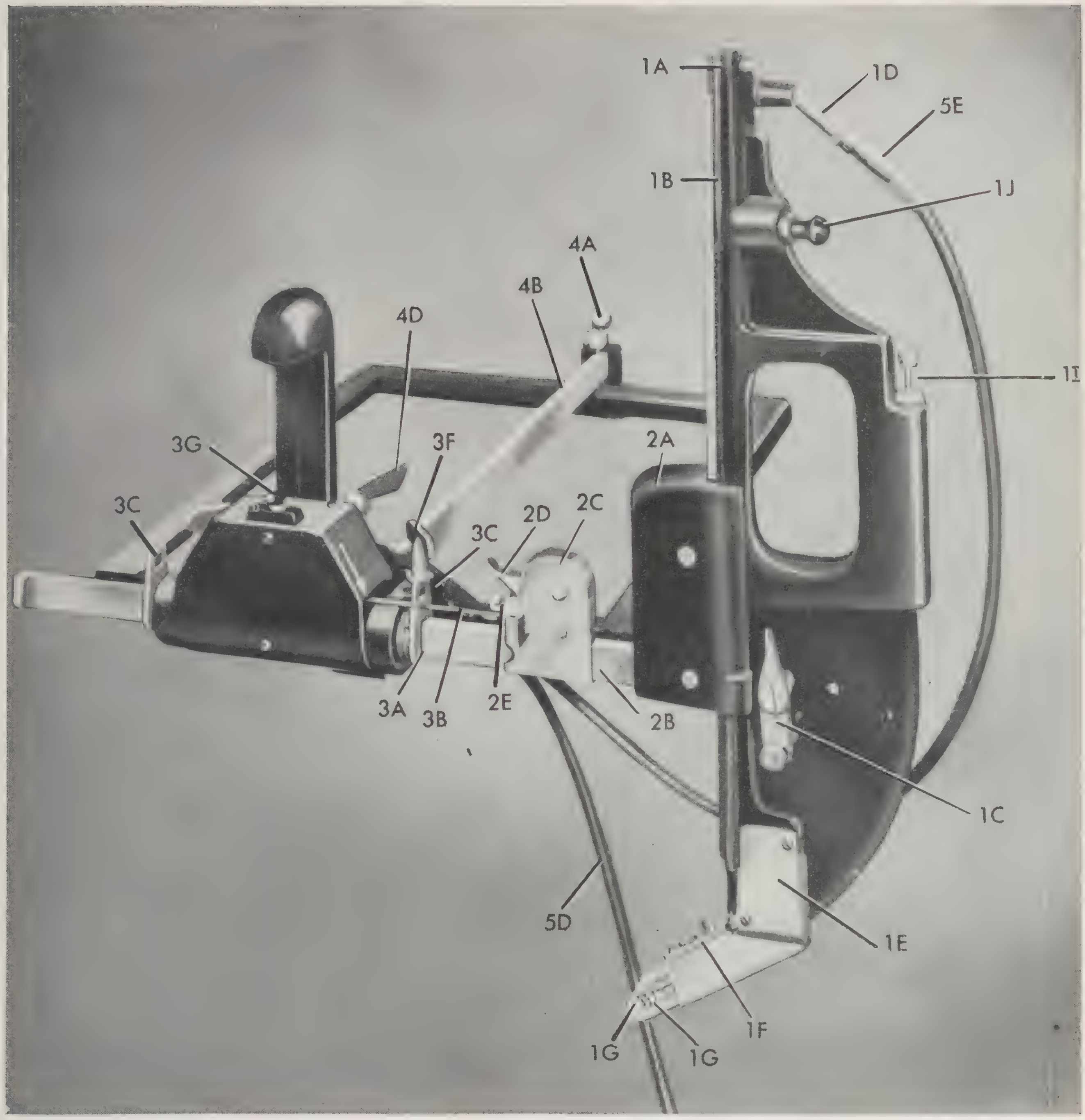


Figure 248. The biplane marker.

c. Function of the working parts. (1) The vertical slide ends at its lower extremity in a lucite tip (1H). This lucite tip is hollow and contains the marking pad (1G). The marking pad will protrude when the plunger (1I), near the grip handle, is pressed down and will recede by spring action. The plunger assembly can easily be taken apart by removing the two screws on the side of the grip handle. The marking pad itself is made of rolled felt. Mounted directly above the lucite tip is a 6-volt lamp. This light lamp is located inside the same sheet metal housing (1E) that incloses the lucite tip. Lucite has the property of conducting light—this property is used to advantage and conducts the light to provide illumination at the place where the patient is to be marked. The sheet metal housing for the lucite tip is hinged in such a manner as to permit easy accessibility to the light bulb for replacement purposes. A 6-volt bayonet base Mazda #51 bulb is used. The sheet metal housing when opened causes the marking tip to protrude

about $\frac{3}{4}$ inch. In this position the pad is accessible for inking. Gentian violet, iodine, or other similar substances may be used as the inking medium. A quick acting snap-lock (1F) holds the marker tip housing in position. When the snap-lock is moved back it disengages from the lock pin and permits the marker-tip-housing to swing open. Two centimeter scales are provided along the one edge of the vertical slide (1B). These two scales are set at right angles to each other so that they can be easily read from either the left or right side of the unit. Two contact rails (1A) are mounted in the vertical slot between the two scales—and by them current is conducted to the light bulb above the lucite tip—and to the light bulb in the vertical slide housing to illuminate the centimeter scales. Current for illumination of the bulbs is provided by the pilot light cables (5). The cable is connected to a 6-volt current source in the X-ray control cabinet. A small connector socket (5E) near the top of the vertical slide permits removal of the cable for packing purposes. A plunger lock (1J) and a catch lock (1C) are part of the vertical slide. The plunger lock (1J) prevents the unit from dropping out of the vertical slide housing when it is installed. The lock catch (1C) is provided to lock the vertical slide in its uppermost position when it is not used.

(2) The horizontal slide (2) has mounted to it at one end of the slide housing (2A) for the vertical slide. This slide housing is plastic and consists of two shells. These shells are joined to form one unit and are grooved to engage and maintain the vertical slide (1). Each of the grooves is lined with felt, permitting smooth operation of the vertical slide. Two screws on the side of the vertical housing may be adjusted should the vertical slide become loosened or difficult to move. A 6-volt Mazda #51 bulb is mounted inside the slide housing. Two contact fingers inside the housing engage the contact rails in the vertical slide to provide current to this bulb. Caution and care should be exercised whenever the vertical slide is placed into the vertical slide housing—the current contacts should not be sprung or damaged during this procedure. On top of the slide housing are two pointers—each indicates the level at which either of the vertical slides is read. The tape clip (2C) is a removable part of the horizontal slide (2) and attaches the centimeter tape (3B) mounted in the horizontal slide housing. By spring action the tape clip (2C) is clamped to the horizontal slide housing or to the horizontal bar. (When the lever (2D) is in the down position the tape clip will engage the horizontal bar (2B); when it is in the up position it will engage the metal end plates (3C) on the horizontal housing; when it is unhooked from the metal end plate (3C) it will ride freely along the horizontal bar.) When the tape clip (2C) is hooked to the metal end plate (3C) the centimeter tape will read zero. By trigger spring action, lever (2D) may be snapped down and, as the horizontal bar is moved away from the housing, the tape clip will pull out the centimeter tape—measuring the amount of horizontal travel from this point.

(3) The horizontal slide housing is mounted on a yoke which permits adjustment rotation in two horizontal planes. This provides the necessary motion to "level" the units. Two spirit levels (3G) at right angles to each other are mounted on top of the slide housing—indicating when the unit is level. Two tape measures with centimeter graduations (3B) are mounted inside the housing. Pointers on the side of the horizontal housing just above the opening through which the measuring tapes emerge indicate the reading point for these tape measures. Rectangular openings (3A) (with adjustable sideplates inside the housing) provide a slide for the horizontal arm (2B). Should this slide become loosened, adjustments may be made by removing the horizontal housing side plate and tightening the four adjustment screws inside the housing. A 6-volt Mazda #51 bulb is mounted in the grip handle above the spirit levels. This bulb provides illumination for the levels and either centimeter tape measure. Current for this bulb is provided by the same cable (5E) that supplies current for the 6-volt bulbs in the vertical slide housing.

(4) The screen clamp (4) is the provision for mounting the biplane marker to the fluoroscopic screen. It consists of a rectangular bar (4B) and two wedge-shaped blocks. One of these blocks is stationary and nonadjustable and has a pinion provision for mounting the yoke of the horizontal slide housing. The yoke fits the rectangular bar by this pin which provides one rotation in the horizontal plane—a lock handle (4D) is provided for fixation of the yoke. The screen clamp is designed so that it can be attached to any fluoroscopic screen frame. To fasten the clamp to a screen, place the two wedge-shaped blocks against either side of the screen frame with the rectangular bar resting on top of the screen. To fix the clamp in this position, tighten the thumb screw on top of the adjustable block (4A).

(5) The pilot light cable has at one end two female connector sockets (5E) and (5D) which fasten to the connections provided on the vertical slide and the horizontal slide housing. On the other end a male connector is fastened to the control of the X-ray machine. An additional short lead with a female connector is provided at the control plug-in side of this cable—for attaching the pilot light cables used on the X-ray field table. A line cord switch is provided on this cable which extinguishes all the biplane marker lights.

d. Operation. With little practice, operation of the biplane marker will be found a comparatively simple procedure. (See fig. 249.) One of the most essential requirements for the successful use of this

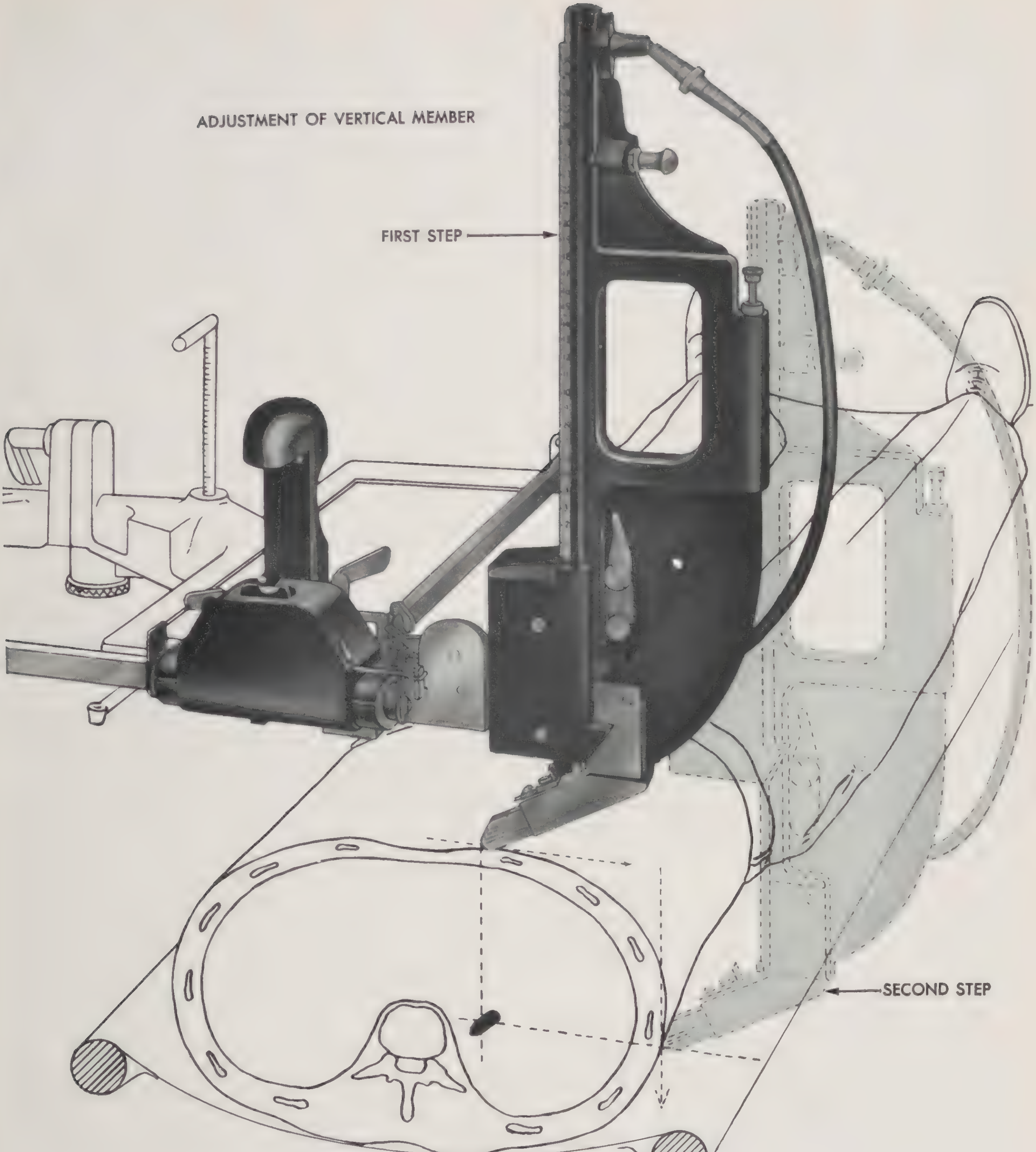


Figure 249. Application of the biplane marker.

apparatus is to be sure that the patient does not move during the foreign body localization—from the moment the fluoroscopic localization is started—until after both marks are made on the skin. (With practice, it will take less than 2 minutes to locate any single foreign body, make the necessary marks on the patient and determine the distance of the foreign body from both of these marks.) After the first marking, and after the distance of the foreign body below this mark has been determined by roentgenoscopy and recorded on the patient, the X-ray machine need be energized no longer. The second stage of the procedure is simply as follows:

(1) Turn on the pilot light (5C) for the biplane marker.

(2) Make certain that the tape clip (2C) for the centimeter scale is locked to the metal end plate (3C) of the horizontal slide housing. Also, be sure that the centimeter scale (3B) is attached to this clip. With the tape clip so arranged, the centimeter tape will now read zero.

(3) In the next phase of this operation, be absolutely certain that the spirit levels (3G), in both planes, are level. Check this periodically throughout the procedure to make sure that this does not change. If necessary, release the two thumb screws (3B) on either side of the yoke and tilt the unit until the true level is reestablished. Thereafter again, fasten the two thumb screws.

(4) Moisten the marking pad with a suitably strong marking fluid, such as gentian violet.

(5) Unlock the vertical slide by releasing the lever (1C) which holds the vertical slide in its uppermost position. This lever should now be placed in its vertical slot so that it will not engage the vertical slide.

(6) Unlock the fluoroscopic screen carriage to permit travel of the fluoroscopic screen in the longitudinal and transverse directions. The biplane marker is attached to this screen and will follow the fluoroscopic screen in both of these motions.

(7) Next, move the biplane marker transversely and longitudinally in the horizontal plane until the biplane marking lucite tip (1H) is above the mark on the patient's skin which was made by the depth scale marker of the field table. Then, move the vertical slide of the biplane marker down until it touches this mark.

(8) Lock the fluoroscopic screen travel.

(9) Read the centimeter scale (1B) on the vertical slide—this reading, added to the depth figure given by the X-ray procedure (first mark on patient), gives the centimeter dimension to which the marker tip has to be lowered to make the second mark.

(10) Snap the tape clip lever (2D) down. This disengages the tape clip from the horizontal slide housing end plate (3C) simultaneously fixing the tape clip to the horizontal slide. Next move the biplane marker assembly toward you and away from the horizontal slide housing until the marker lucite tip clears the side of the patient. (See fig. 249.)

(11) Move the vertical slide down to the centimeter reading (depth of foreign body below first mark on patient plus the reading of the scale while the tape was aligned with the first mark). When the scale is brought to this centimeter figure, move the biplane marker in toward the body, recheck the vertical—then mark the skin by pressing the plunger of the biplane marker. This is the second mark.

(12) Next, without moving the biplane marker, read the centimeter tape (3B) to determine the horizontal travel. This reading will now give the centimeter distance from the foreign body to the second mark. This dimension should also be written on the patient's skin. (See par. 270.) In each case, the depth value should be recorded on the patient's skin to avoid any possible confusion or forgetting of numbers.

(13) If this is the only localization needed for this patient, raise the biplane marker and lock in the rest position with lock (1C). Slide the fluoroscopic carriage and biplane marker out of the way and clear the table for the next patient. Otherwise, repeat procedure for the next foreign body. If the patient has more than one foreign body, it is necessary to identify each pair of marks relating to any one foreign body. For example, a circle, triangle, square, cross, etc., should be used.

(14) The biplane marker may be used from either side of the table, or on either end of the fluoroscopic screen. The screen clamp may be adjusted so that the stationary block is at the head end of the fluoroscopic screen, or at its foot end or even to either side of it. However, the horizontal slide arm may be inserted into either side of the horizontal slide housing. The tape clip will also attach to either side of this housing. (Be certain to unhook the tape measure from the tape clip before removing the horizontal slide arm. The second centimeter tape may be attached to the tape clip on the other side after the changeover has been made.) The deciding factor as to the side from which the biplane marker is to be operated, is the location of the foreign body in relation to the midline of the patient.

270. REPORTING OF LOCALIZATIONS AND FINDINGS. **a.** Reporting of localizations should be accomplished in a dual manner: by way of the markings onto the skin surface of the patient (that is, as mentioned in paragraphs 265 and 266—the spottings with respect to the roentgenoscopic procedure—as well as the spotting as accomplished with the biplane

Last name: Lasky | First name: Arthur | Initial: E.

Army serial No.: 3358032 | Grade: Sgt.

Company: D | Regiment and arm or service: 342 Inf. | Division: 27th

Age: 20 | Race: W | State: N.J. | Service: 1 4/12 | Source of admission: Command

Received at (hospital and location): 6th Evac. Hosp. Foggia, Italy | Date: 10-30-43

Diagnosis: WIA MW
Upper arm, shoulder
and thorax

Line of duty: Yes

Changed and additional diagnoses, operations, with dates:

Fragments in upper
arm and thorax

Disposition: 12th Surg. Hosp. | Date: 11-1-43

16—15950

John Hannan
Capt. M.C. Signature of Surgeon.

Received at (hospital and location): 12th Surg. Hosp. Naples, Italy | Date: 11-1-43

Changed and additional diagnoses, operations, with dates:

Patient supine:
Δ oblong shrapnel 5 X 1.5 cm.
3 lying lateral to greater
2 tuberoscity, left humerus.
No fracture.
⊙ Triangular shrapnel,
1 cm 7 left upper thorax -
5 fracture posterior 3rd rib.
∟ Jagged fragment, 3 X 1 cm.
8 left mid thorax
9 Pneumothorax - Nov. 2, 1943
about 50 % collapse

Disposition: 48th. Gen. Hosp. | Date: 12-4-43

Henry G. Moehring
Lt. Col. M.C. Signature of Surgeon.

Received at (hospital and location): | Date

Figure 250. Reporting of roentgenoscopic findings.

marker described in paragraph 269) and also by way of a written report (using standard forms such as WD, MD Form No. 52c or the Emergency Medical Tag or such as WD, MD Form No. 55—series).

b. The spottings (that is, considering one spotting on the horizontal plane and one spotting on the vertical plane) concerned with each foreign body should be identified by characters. On the skin surface of the patient or on overlying dressings, a dot should be marked over the foreign body. Since several such dots might be made, either carelessly or because of there being a number of foreign bodies contained, the precise marking should individually be identified by means of an outer character such as a circle, square, or triangle; an intersecting line; a nearby acute, obtuse, or right angle, etc. Near such identification the depth of the foreign body should be recorded. The same identification should be used to identify both spottings (that is, onto the horizontal and vertical plane pertaining to any one foreign body). These same characters should be used in making the written reports, in which case the depth values should be recorded beneath the character serving to identify each foreign body. As shown in figure 250, only one record of each character should be included in the written report. Beneath each such character on the report there should be two numerical values: the upper number indicating the depth in centimeters at which the foreign body is located beneath the horizontal skin surface; the second numerical value indicating the depth in centimeters at which it is located beneath the vertical skin surface. Unnecessary details should not be included, though information should be recorded as to the position of the patient when the localization was accomplished, the approximate size and character of the foreign body, its relations to anatomical landmarks, and the apparent condition of the tissues (particularly the skeleton).

271. REORIENTING DEVICE. a. General. The reorientating device is a component of Item No. 96191; it is packed with the biplane marker. It is to be used by the roentgenologist when the surgeon requires his assistance, in the operating room. It is contemplated that with foreign bodies of any considerable dimensions, application of the reorientating device should not be necessary. The two-plane spottings as accomplished by the roentgenoscopic localization and by the application of the biplane marker, should ordinarily suffice for orientation of the surgeon. However, where difficulty is anticipated, the reorientating device should be fixed to the operating table, ahead of time and its application prearranged, by the roentgenologist.

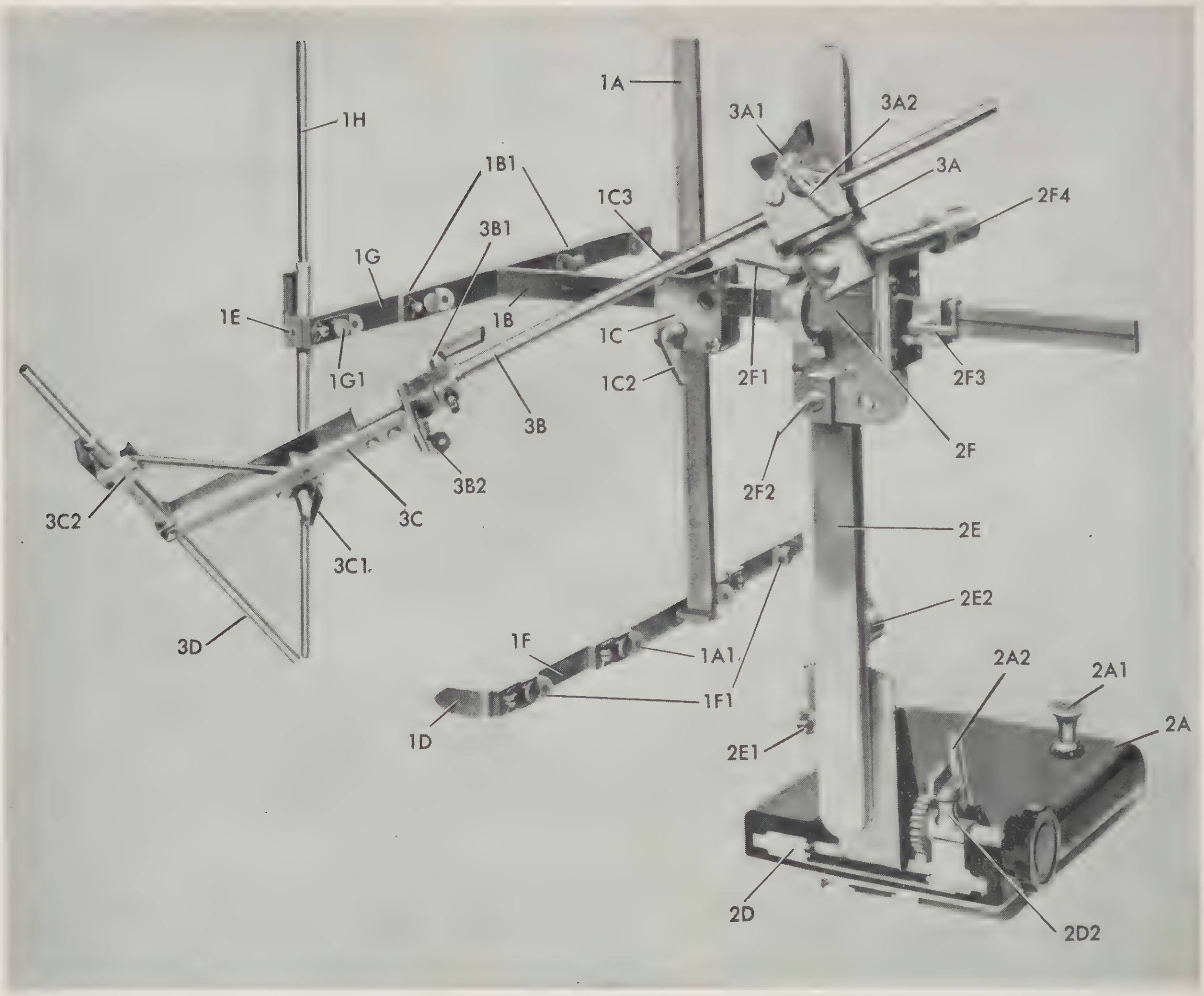


Figure 251. The reorientating device, complete.

b. Working parts. The reorientating device consists of the following parts (fig. 251):

(1) REORIENTATING CALIPER
- 1A. Vertical graduated scale bar
  - 1A1—Release catches
- 1B. Horizontal graduated scale bar
  - 1B1—Release catches
- 1C. Slide block
  - 1C1—Lock-horizontal scale bar
  - 1C2—Lock-vertical scale bar
  - 1C3—Spirit levels
- 1D. Pointer
- 1E. Probe sleeve
- 1F. Probe Sleeve extension bar
  - 1F1—Release catches
- 1G. Pointer extension bar
  - 1G1—Release catches
- 1H. Vertical probe

(2) CALIPER SUPPORT STAND
- 2A. Support stand tunnels
  - 2A1—Base plate lock
  - 2A2—Release lever
- 2B. Tunnel clamps
- 2C. Tunnel clamp screws
- 2D. Tapered slide
  - 2D1—Knob for longitudinal vernier slide
  - 2D2—Lock for vernier slide
- 2E. Support stand
  - 2E1—Lock pin for vertical support
  - 2E2—Adjustment lever for vertical support
- 2F. Slide block with rotatable sleeve
  - 2F1—Lock lever for rotatable sleeve
  - 2F2—Lock lever for vertical adjustment (2F)
  - 2F3—Lock for horizontal caliper slide bar
  - 2F4—Bosses for universal block attachment

(3) AUXILIARY PROBE DIRECTOR
- 3A. Universal block
  - 3A1—Lock for universal block
  - 3A2—Probe shaft lock lever
- 3B. Probe supporting shaft
  - 3B1—Lock lever for 360° motion of angulator
  - 3B2—Angulator release catch
- 3C. Probe angulator
  - 3C1—Angulation lock lever
  - 3C2—Auxiliary probe sleeve
- 3D. Auxiliary probe

c. Application. There are four combinations with which the reorientating device may be applied:

(1) *Simplest combination using caliper along.* The patient is brought to the operating table with two marks related to the position of the foreign body, the distance of the foreign body from each mark having been inscribed onto the patient's skin, with appropritate identifying characters. (See fig. 250.) The reorientating caliper is set to these dimensions given on the skin. The horizontal arm 1B is extended so that its centimeter scale reading at the tip of the arrow on the slide block 1C, coincides with the depth value calculated by means of the biplane marker. Likewise, the vertical arm 1A is adjusted so that the reading on its centimeter scale, at the level of the arrow on the slide block coincides with the depth value which was calculated by means of the roentgenoscopic localization. Thus the color code blue (found on the T-arm of the horizontal member and also on its clamp) is concerned with the depth calculation developed by the biplane marker while the color code red (found on the T-arm of the vertical member and its clamp) is concerned with the depth calculation developed by the roentgenoscopic localization. All that is necessary in most cases is to position the caliper (without changing any clampings) so that the probe sleeve 1B is in direct apposition and contact with the skin marking concerned with the roentgenoscopic localization. Thereafter, the caliper is positioned until the spirit levels indicate true leveling in both directions. If, then, the pointer 1D does not project and is not in immediate contact with the skin marking provided by the biplane marker, the patient must be rotated until such contacts and relations will hold true. (See fig. 252.)

(2) *Combination using caliper with extension bar.* If it is comtemplated that rechecking of the relations will be required with probings extending actually into the operative wound, this caliper may be used in the very same manner as described above but with extension arms 1F and 1G respectively. It

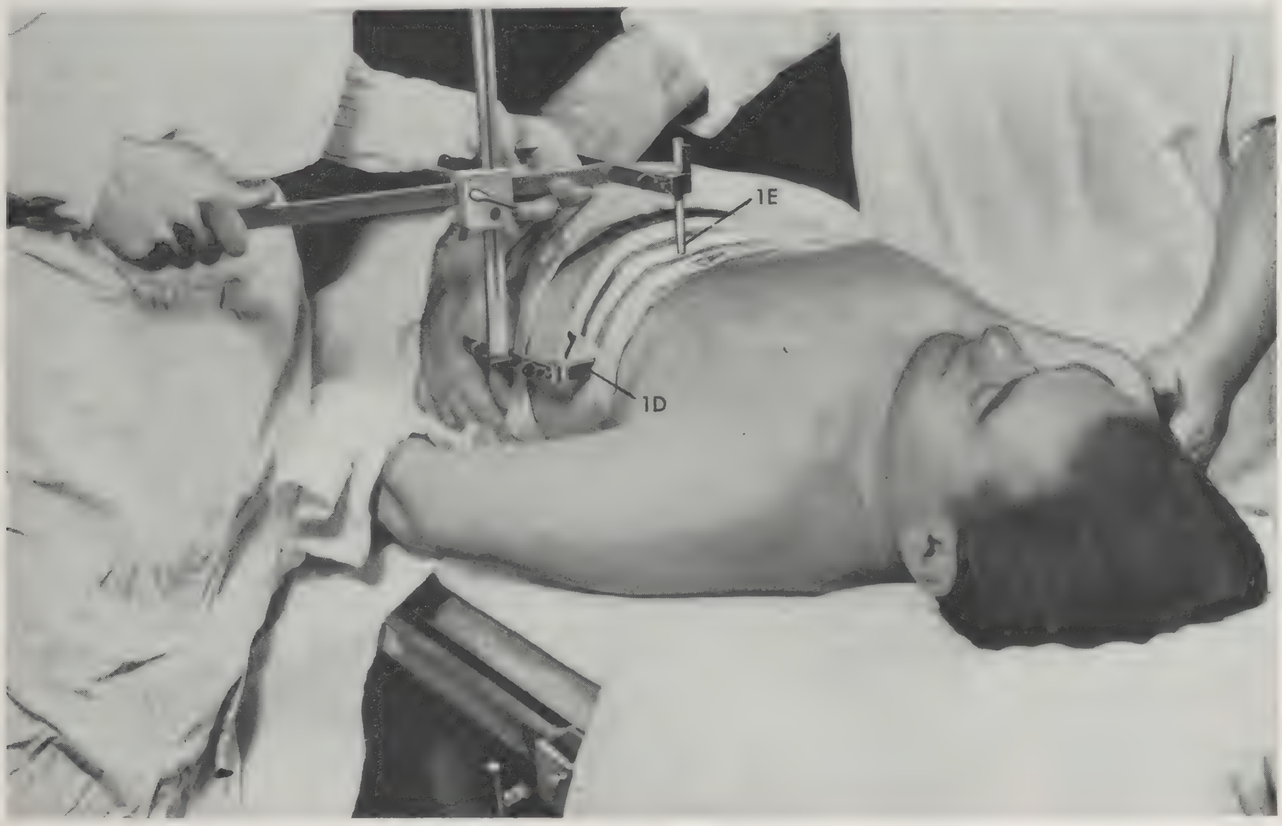


Figure 252. Localization caliper—the simplest application of the reorientating device.

must be borne in mind that after the incision has been made, even with the use of the sterilizable extension bars 1F and 1G and the probe sleeve and pointer attachments, thereto, it will not be possible to accomplish accurate repositioning of the caliper. As an expedient which might serve for guidance relative to the proper positioning for the probe sleeve and probe, a lineal iodine marking may be extended beyond the surgically prepared field to serve for indication of one and preferably both planes pertaining to the skin marking through which the incision has been made.

(3) *Combination using caliper, extension bars, and caliper support stand.* A more definite procedure would be to make use of the caliper support stand. In a convenient location, at a distance from the patient, mount the caliper with its extension bars assembled as described above into slide lock 2F. Thereafter, insert the pedestal slide 2D and attachments with the tunnel 2A. (See fig. 253.) It may be necessary to change the position of the tunnel in order to adjust the pointers of the caliper to an alignment with the two markings on the patient. Otherwise, this alignment can be accomplished by means of a rack and pinion adjustment contained on the pedestal of the stand. Thereafter, adjust the rotatable sleeve of the vertical slide to provide for true leveling with respect to the lengthwise plane of the patient and operating table. Having thusly accomplished true leveling of the caliper with respect to both directions on the horizontal plane, it should now be lowered so that the tip of the vertical probe sleeve is in contact with the uppermost markings on the patient. It may be necessary to slide the horizontal arm of the caliper either outward (that is, away from the patient) or inward (that is, toward the patient) making use of the clamping of the rotatable sleeve of the vertical slide. It might also be necessary to slide the horizontal arm of the caliper toward the head or toward the foot of the patient, making use of the rack and pinion adjustment of the pedestal (providing a range of 8 cms) or by means of readjustments of the tunnel itself. (See fig. 254.) Either or both of the adjustments and possibly a vertical adjustment should be accomplished until the tip of the probe sleeve is immediately in apposition to the uppermost marking on the patient, as mentioned above. Thereafter, the horizontal side marker of the caliper should be immediately in apposition to the side marking of the patient. If those relationships do not pertain, the patient must be carefully rotated and further adjustments must be made on the supporting stand (making no changes in the caliper, itself), until the two pointers are in direct apposition to their respective markings. Securely fix all clamps to counteract any further deviations in relation of the caliper to the stand and the patient. Now, the patient has been positioned on the operating table so that all relations such as existed during roentgenoscopy have been reestablished; the foreign body lying in a perpendicular plane with respect to the uppermost skin marking and in the horizontal plane with respect to the side skin marking. Thereafter, release the gear sector lock on the vertical member of the support stand 2E and angle the vertical support together with the caliper itself, away from the patient. (See fig. 255.) This permits easy removal of the pedestal and vertical column together with the caliper by releasing lock 2A1 and forcing lever 2A2, in order to eliminate interference during surgery. Except for the fixation tunnel, the other components should be positioned into the *second* tunnel on the side stand or side table. The stand and caliper may be returned to the operating table tunnel at any time during operation to recheck position or assist in probing for the foreign body. The unit will return to the same position on the operating table and the caliper points will reestablish the same relations as previously described, provided none of the adjustments have been disturbed.

(4) *Combination employing all components.* In case the surgeon must approach the foreign body by way of a plane other than through either of the two skin markings, it may be desirable to make use of the auxiliary probe director—3. Extend the auxiliary probe arm, after loosening clamps 3A1 and 3A2, until the tip of the probe angulator is in immediate contact with the middle of the incision as anticipated by the surgeon. (See fig. 256.) Securely fasten these two locks and all other locks. Thereafter, none of these locks should be disturbed excepting the locks on the probe angulator. Next, remove the stand and all attachments. The vertical member may be angulated if necessary, as shown in figure 255, permitting convenient removal of the vertical stand and all attachments. After placing the vertical stand and all attachments into the second tunnel (fixed onto a side table), true level of the horizontal arm must again be reestablished and the vertical member secured by lock 2E2. (See fig. 257.) Thereafter, one probe is inserted into the vertically positioned probe sleeve of the horizontal member and extended downward until the reading on its scale coincides with the depth measurement of the foreign body as determined by the roentgenoscopic procedure. The auxiliary probe is then maneuvered by the release of clamps 3B1 and 3C1 (fig. 257) until the tip of this probe is in immediate contact with the tip of the vertical probe just mentioned. The centimeter projection value concerned with the extension of the auxiliary probe is then noted and records should be made of this value for future reference. This measurement represents the distance from the surgeon's mark to the foreign body and the probe also points in the direction of the location of the foreign body from that mark. The caliper is no longer needed after the auxiliary probe angulation

Figure 253. Combination using caliper, extension bars, and caliper support stand.

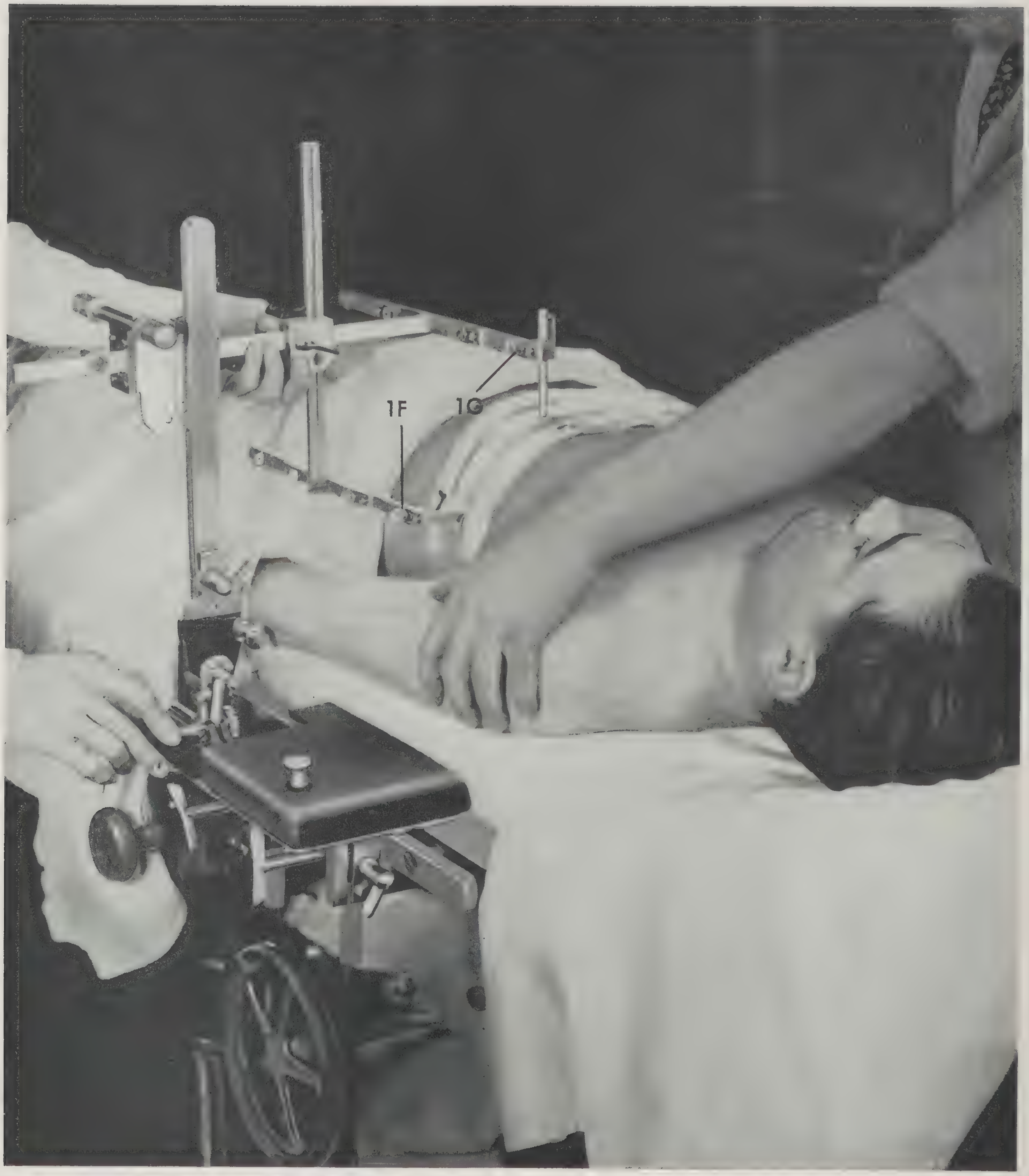


Figure 254. Reorientation of the patient.

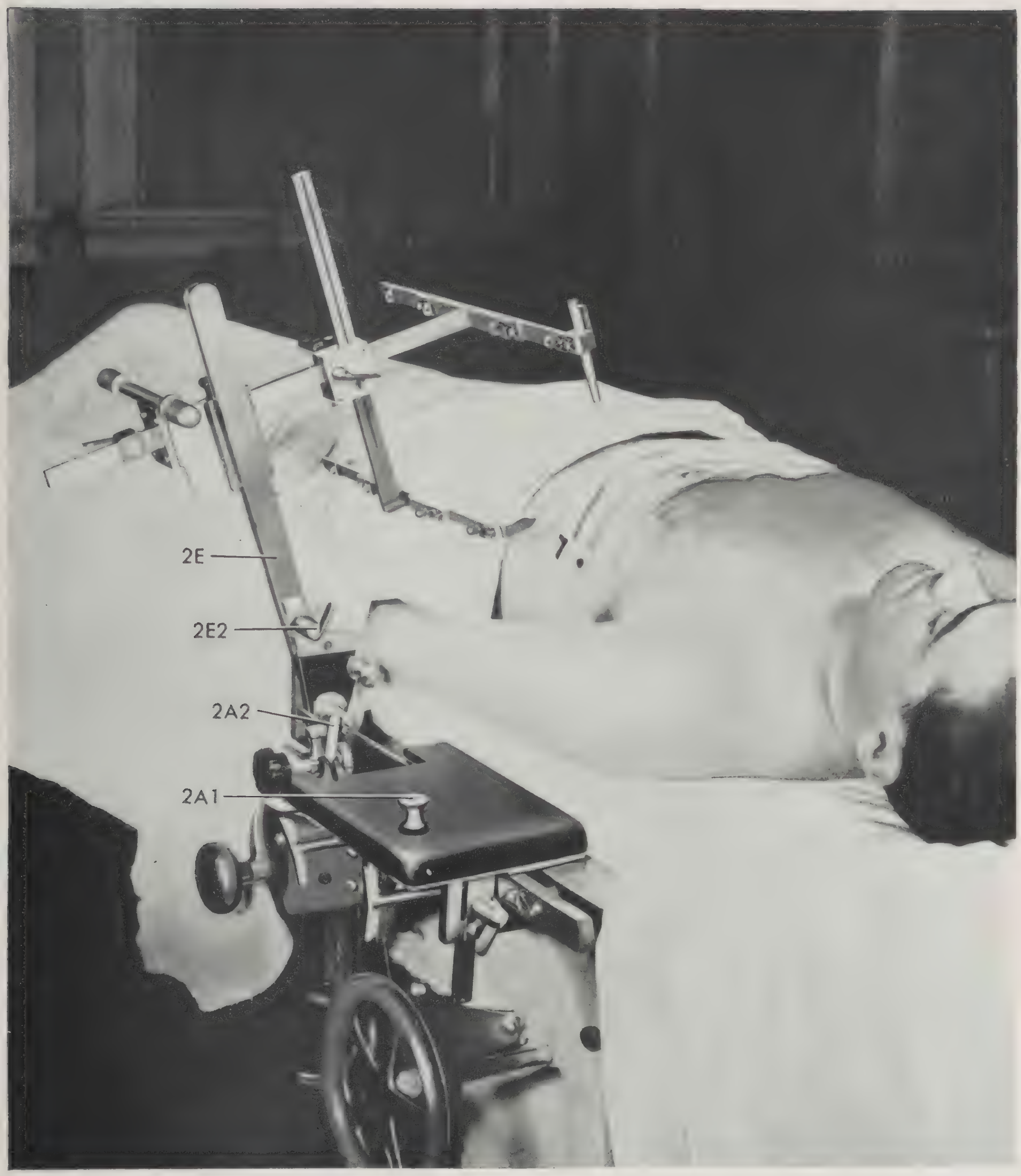


Figure 255. Removing the caliper from the operative field.

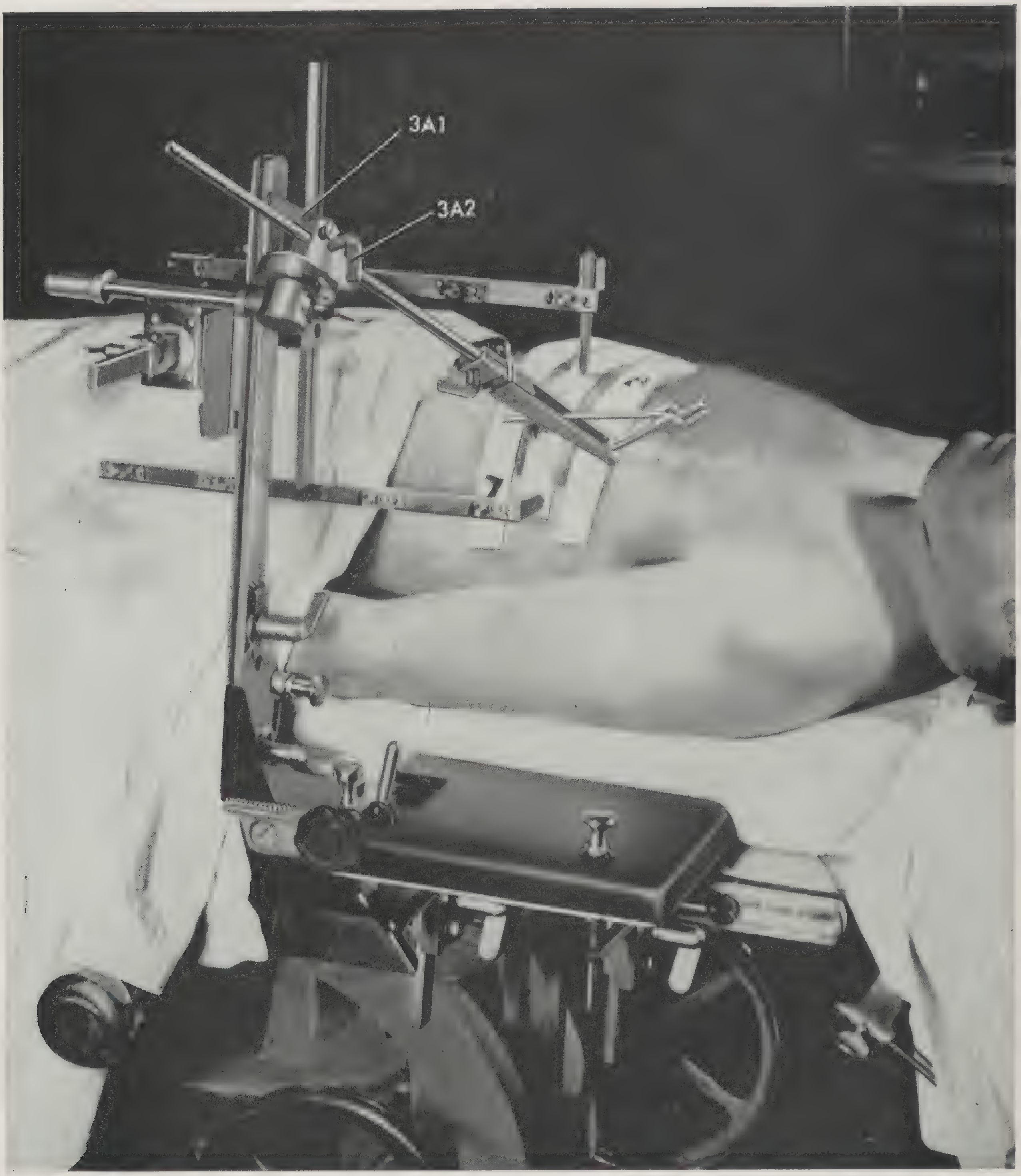


Figure 256. Introducing the auxiliary probe director.

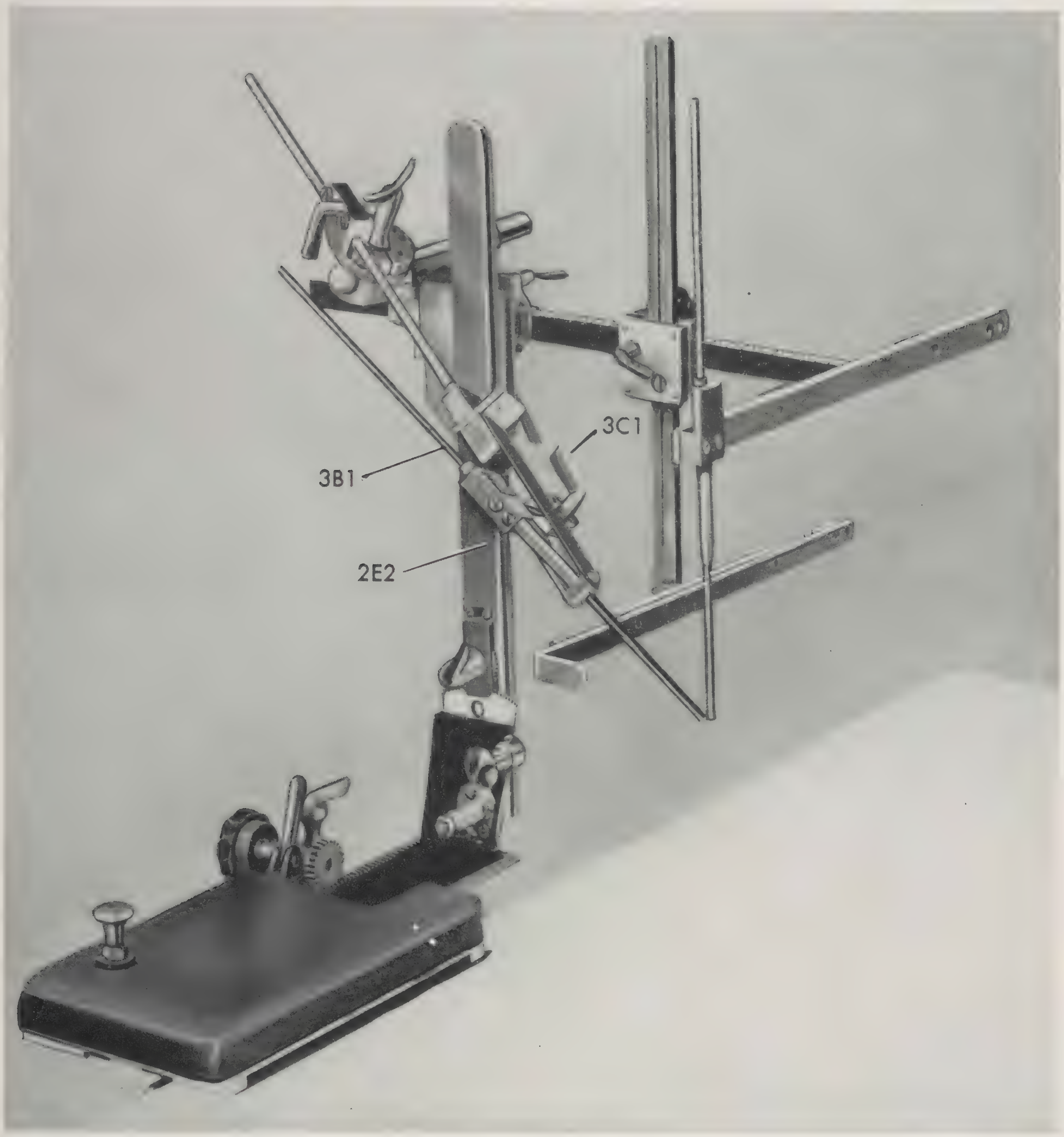


Figure 257. Set-up for localizing foreign body (at side table) with respect to auxiliary probe director.

has been made. However, before removing the caliper, it is advisable to record the centimeter measurement on the horizontal arm of the caliper at the edge projecting out of the rotatable sleeve. This may be of value later on, if it is necessary to recheck the apposition of the vertical and the auxiliary probe, should the unit be accidentally put out of alignment. The auxiliary probe with its probe angulator should now be removed from the probe supporting shaft and sterilized for future application right into the operative wound. After sterilization, the probe angulator together with the probe should be reattached under *aseptic* precautions to the probe supporting shaft before reinserting the vertical stand into the tunnel. In case the surgeon encounters difficulty in locating the foreign body, without disturbing any locks, the vertical stand together with the auxiliary probe should be repositioned into the tunnel on the operating table. It may be necessary to insert the caliper for reestablishing the level of the horizontal plane, but this can be done by inserting it into the vertical slide on the vertical column, from the side opposite that previously utilized. Those portions of the supporting stand which have not been sterilized should be covered with sterile towels.

SECTION II. ROENTGENOGRAPHIC LOCALIZATION

272. GENERAL. a. Localizations of foreign bodies in the eye require precise measurements and calculations with respect to the center of the pupillary diaphragm and the wall limits of a normal eyeball. It is not practical to base measurements of these foreign bodies beneath a surface marking as provided

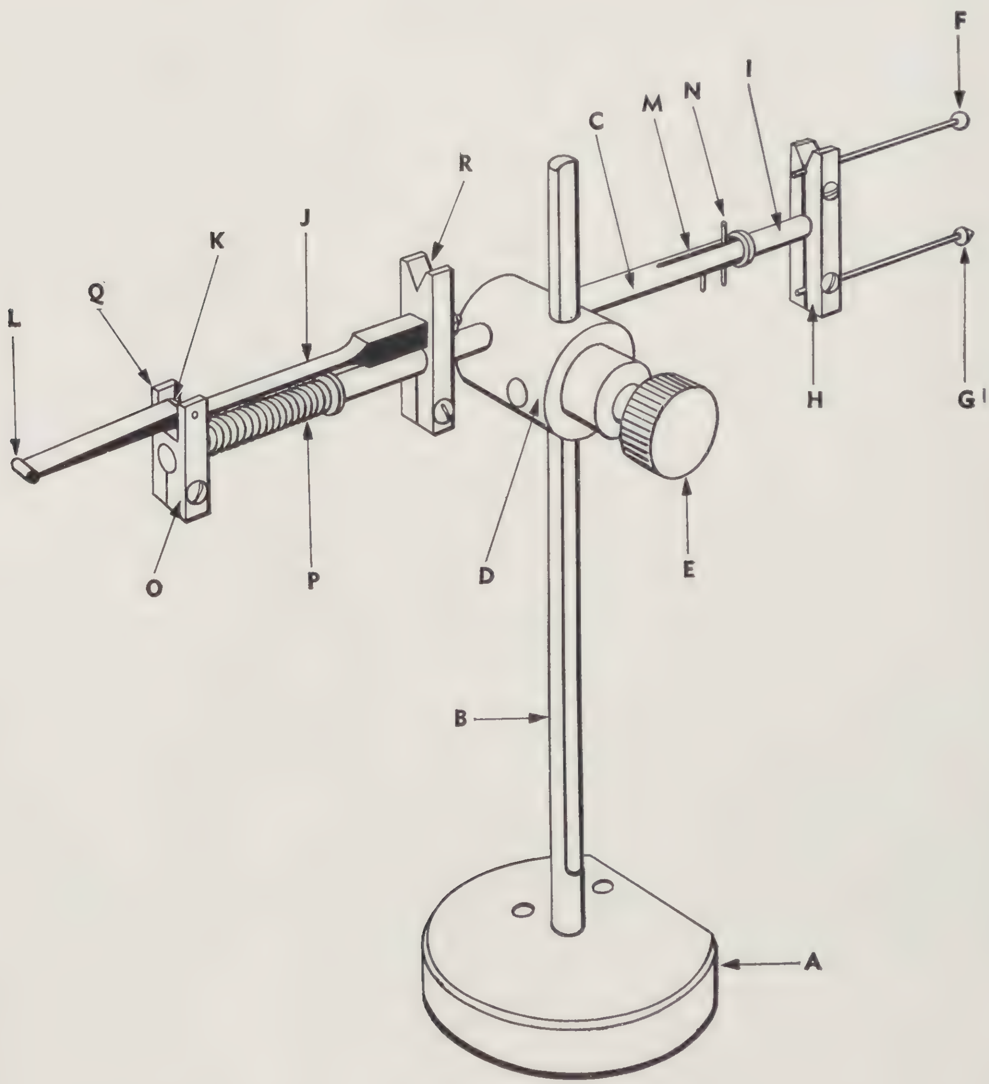


Figure 258. Localizer for foreign bodies within the orbit.

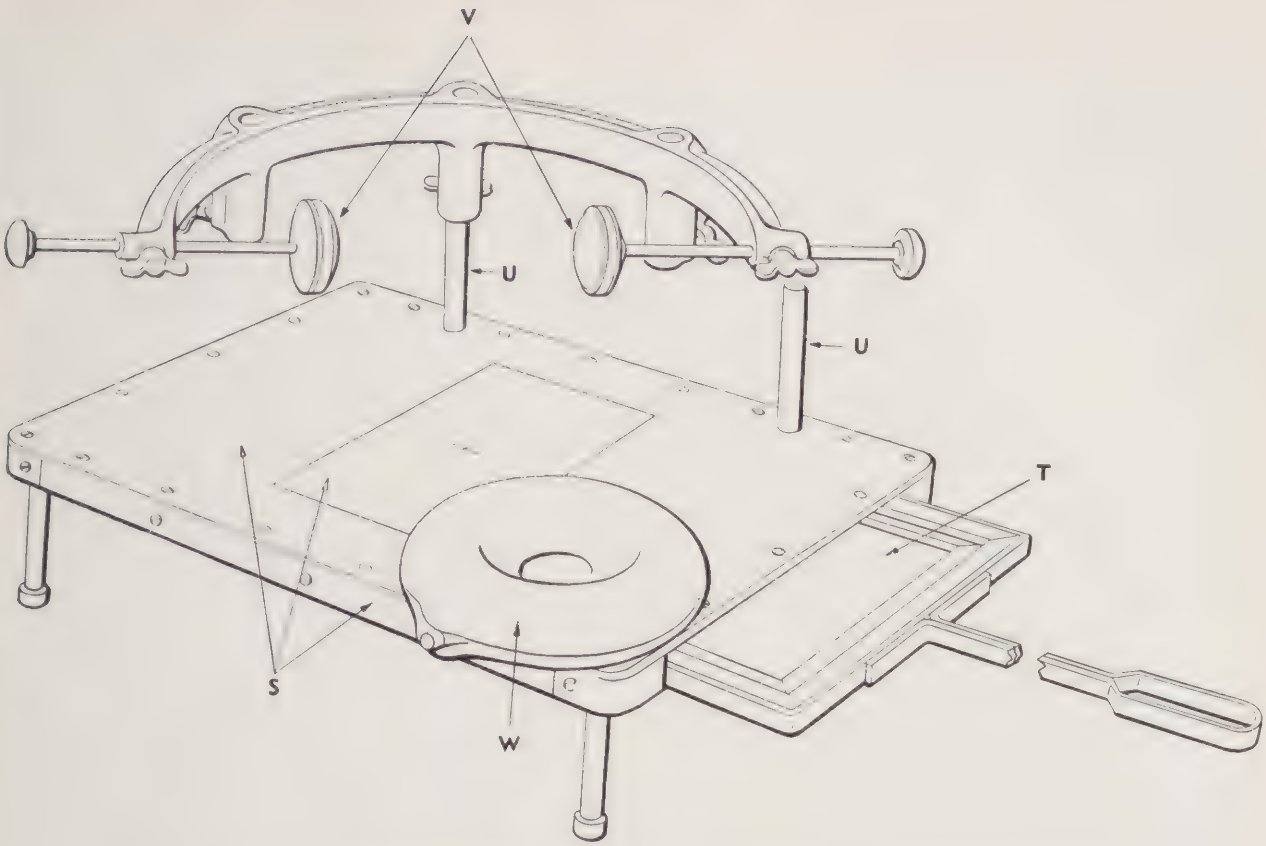


Figure 259. Head support and film tunnel for localizer of foreign bodies within orbit.

with the routine procedure described in section I of this chapter.

b. Apparatus has been designed and equipment is commercially available for a number of different methods for accomplishing this work. In the United States Army, particularly with the application of standard field X-ray equipment, the "Sweet method" has seemed the most practical. It provides for calculating measurements in three different planes; it does not require the use of elaborate equipment and the technical procedure is simple. Using this method, it is not necessary to anaesthetize the eye nor to adapt orienting landmarks.

273. APPARATUS REQUIRED. **a.** The localizer unit consists of the following construction features (fig. 258):

(1) A heavy metal base *A*, serving for support of the unit.

(2) A vertical supporting arm *B*, providing for adjustment and fixation of the horizontal supporting channel arm *C*.

(3) A supporting bracket *D*, having a setscrew *E*, providing for raising and lowering and fixation of the horizontal channel arm *C*.

(4) A metal ball *F* and metal cone *G*, spaced 15 millimeters apart, and supported on bracket *H* which in turn is fixed to rod *I* which moves within horizontal channel arm *C*.

(5) Spring catch *J*, having engaging notch *K* and trigger release *L*, serving for forward setting of the ball and cone and then release of them to the extent of exactly 1 centimeter as controlled by slot *M* in the supporting channel arm *C* and stops *N* mounted on rod *I*.

(6) Bracket *O* fixed to rod *I* serving for support of recoil spring *P* and catch *Q* for engaging notch *K*.

(7) Sighting notches *R*, serving for the true positioning of the ball *F* in apposition to the center of the cornea.

b. The headrest unit consists of the following construction features (fig. 259):

(1) A special pedestal tunnel *S*, having lead protection over its upper, outer thirds so as to provide for exposure of one-half of an 8- by 10-inch film as contained in a cardboard holder and positioned in sliding film tray *T*. (Thus, it is a serialographic device—see par. 257.)

(2) Vertical supporting columns *U*, serving for support of the head clamp *V*.

(3) Pneumatic ring *W*, for support of the patient's head.

274. TECHNICAL PROCEDURE. **a.** The patient is placed on the X-ray table, lying on the same side as the eye in which a foreign body is thought to be contained. The pedestal tunnel of the headrest is placed beneath the head and the head is positioned so that the region of the eyes is superimposed over the portion of the tunnel which is unprotected by lead (place pneumatic ring under head, if desired). The supporting head fixation pads are then positioned to fix the head to a position wherein the midsagittal plane of it is parallel to the film.

b. Place localizer on stand, ball and cone side nearest eye. Sighting through notches *R*, align metal ball *F* to center of cornea (center of pupillary diaphragm). Fix set screw *E*. Engage horizontal rod *I* by means of spring catch *J*, at notch *K*. Have patient close eyelid; advance localizer unit until metal ball *F* presses into the lid to an extent equivalent to the thickness of it. Release trigger *L* and allow patient to open eyelid; thereafter, instruct patient to maintain a focus onto an object at a distance and in line with sighting notches *R* and metal ball *F*. These relations are demonstrated in figure 260.

c. Align focal spot of X-ray tube over metal ball *F* and cone *G* (focal spot, ball, and cone being aligned by principal ray in perpendicular relation to film) and position tube at a working distance (30 inches recommended) above film. Position film in cardboard holder in sliding film tray *T* so that one-half of it lies beneath the unprotected portion of the tunnel *S* (beneath the eye portion of the patient's head and beneath the localizer ball and cone). After providing identification, make an exposure as for a slightly underexposed lateral paranasal sinus study, such as the following:

Distance	*Milliampere-seconds*	*Kilovoltage*
30 inches	60	70

Slide film in tray so that the unexposed portion of it is placed into position for a second exposure. Shift X-ray tube approximately 6 inches toward the feet of the patient and make a second exposure, using the same factors as previously. The resultant roentgenogram should appear as shown in figure 261.

275. CALCULATION PROCEDURE AND DEVELOPMENT OF INDICATING CHART. **a.** On the first of the two exposures contained on the roentgenogram the ball and cone should be superimposed, while on the second exposure the ball should be projected to a relatively high level in relation to the cone (that is, with cardial shift of the tube). The entire orbit of the patient should be visualized. Search should be made for one or more foreign bodies. With consideration of any one foreign body, the localization is plotted onto a special coordinate chart (fig. 262), as follows:

(1) Etch a line on the first exposure of the film through the horizontal axis of the ball and cone, thereby projecting the optic axis of the eye.

(2) Etch a second line at right angles to and intersecting this one and through the center of the outline of the foreign body.

(3) Using a small pair of dividers, set its points,—one to the edge of the indicator ball and the other to the intersection of the horizontal and vertical lines just drawn. Transpose this distance onto the coordinate chart shown in figure 262, as indicated at the intersection of lines *B* and *A*.

(4) Again, using dividers, set its points, one to the intersection of the horizontal and vertical etching just described, the other point to the center of the outline of the foreign body. Transpose this distance onto the coordinate chart in its proper relation to the optic axis, at *F*. (This procedure serves to locate the foreign body at *F*, anteroposteriorly in relation to the lateral vertical plane.)

(5) Extend line *A* so as to cross over the front view of the orbit (as shown on the coordinate chart) and extend line *B* to the oblique boundary of the chart.

(6) Extend a line *C* horizontally from the location of the foreign body at *F*, parallel to line *A* and across the front view on the chart.

(7) Using the second exposure of the roentgenogram, etch one line through the axis of the ball and its supporting arm and another line through the axis of the cone and its supporting arm.

(8) Etch a third line at right angles to and intersecting these two lines and through the center of the outline of the foreign body.

(9) Using the dividers, set its points, one to the center of the outline of the foreign body, the other to the intersection of the etching concerned with the ball; transpose this spacing onto coordinate chart in relation to the outline of the ball as shown by point *D* on line *E*. In the event that the foreign body lies on the same side of ball axis as does the cone, this distance should be laid off downward from the point of intersection of lines *A* and *E*.

(10) Again, using the dividers, repeat this procedure with respect to the center of the outline of the foreign body and the intersection of the etching concerned with the cone, transposing this spacing onto the coordinate chart in relation to the outline of the cone as shown at point *G* on line *H*.

(11) Extend a line through points *G* and *D*, intersecting line *C* at F'. (These transpositions serve to locate the foreign body at F', laterally, in relation to the front-view vertical plane.)

(12) Extend line *I* from the intersection of line *B* and the oblique boundary of the chart at *J*, parallel to line *C*, so that this line crosses the horizontal outline of the orbit.

(13) Extend another line *K* at right angles to line *C*, from the point F', so as to intersect line *I* at point F''. (These extensions serve to locate the

Fig. 260. Patient positioned for localization of foreign body within orbit.

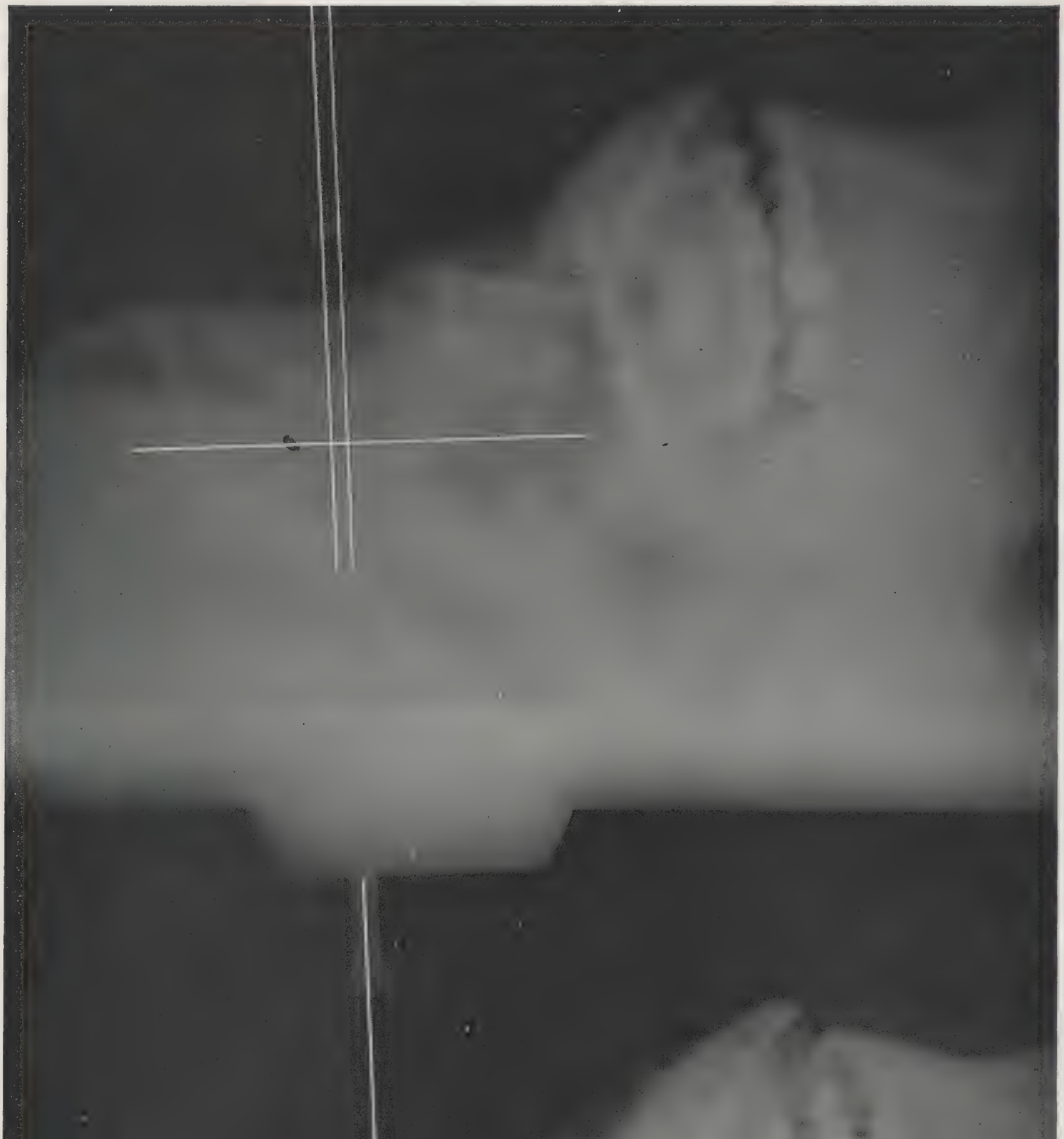


Figure 261. Roentgenogram as used for localization of foreign bodies in orbit.

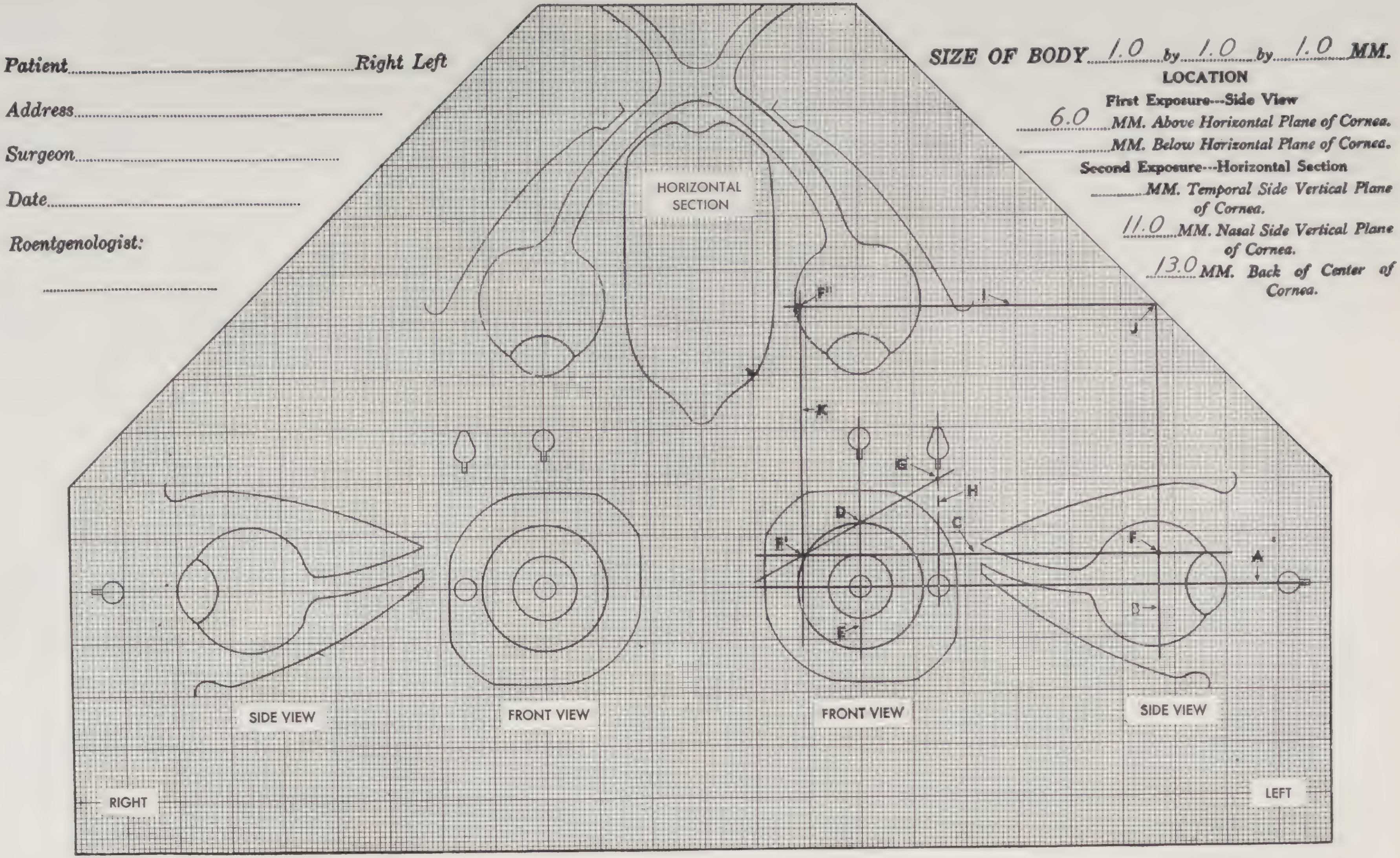


Figure 262. Sample report of localization of foreign body in orbit.

foreign body at F'', laterally, in relation to the horizontal plane.)

b. By merely counting the millimeter coordinate spacings, it is possible to render a report as to the location of the foreign body with respect to the central axis of the eyeball and in relation to the side view, front view, and horizontal plane. Using the chart as shown in figure 262, these measurements should be reported in the upper right corner.

276. IMPORTANCE OF PRECISION IN TRANSPOSITIONS AND PLOTTINGS. Extreme care should be exercised in making all transpositions. Too frequently, plottings are made so that the localizations are indicated either on the wrong eye or on the wrong side of the central axis in one or another plane. Also, all plottings may be properly accomplished but the reporting inaccurately made (that is, with consideration of "above the horizontal plane" versus "below the horizontal plane" or "on the temporal side" versus "on the nasal slide"). Such errors may lead to unnecessary extensions or duplication of surgery.

277. APPLICATION OF METHOD WITHOUT CHART (ITEM 60510). a. Method. It is possible to localize foreign bodies in the eye by means of the Sweet-Bowen apparatus without the use of plotting the values on the eye charts (Item 60510) ordinarily available. The procedure for localizing the foreign body roentgenographically is just as previously described. On film I (fig. 261) the foreign body appears in a certain position and on film II it appears in a new position because of the tube shift for the second exposure. To utilize this simple method when the eye charts are not available, the following procedure is suggested:

Step 1—Construct lines on the film as for the method when using the eye charts. (See fig. 261.)

Step 2—On film I, measure the distance (a) of the foreign body cephalad or caudad from (i), as described above. (See par. 276.) *This measurement gives the distance of the foreign body above or below the horizontal plane of eye.*

Step 3—On film I, measure the distance from the point (i)—the intersection of the two lines on film I—to the edge of the image of the superimposed ball and cone of the localizer apparatus. Subtracting 10 mm (that is, ball and cone shift) from this measurement gives *the distance of the foreign body behind corneal surface of eye.* This completes the localization of the foreign body in two directions—above or below the horizontal plane of the eye and the distance behind the cornea of the eye. There remains the need to localize the foreign body with respect to the nasal or temporal aspects (that is, distance from the midvertical plane in nasal or temporal directions). This distance in the nasal or temporal direction is determined with the aid of two measurements from the film and by the use of the simple formula given below.

Step 4—On film II, measure the distance (b) from the foreign body to the ball axis.

Step 5—Measure the distance (c) between the ball and cone axis.

Step 6—The numerical values of a, b, and c as measured on the films are substituted in the following simple formula.

Distance of foreign body nasal or temporal from

$$\text{optic axis} = \frac{\pm a \pm b}{c} \times 15$$

Where:

a = distance of foreign body from optic axis on film I.

b = distance of foreign body to ball axis on film II.

c = distance between ball and cone axis.

15 = distance in mm between ball and cone of localizer.

Step 7—In order to determine whether the foreign body lies nasally or temporally, the proper signs for a and b to be used in the formula are determined as follows:

(a) When the foreign body on film I lies the same direction (cephalad or caudad) from the optic axis as the ball on film II lies from the cone, (a) should be designated "minus" (−) in the formula. When the foreign body on film I *does not* lie in the same direction from the optic axis as the ball lies from the cone in film II, (a) should be designated "plus" (+) in the formula.

(*b*) When the foreign body on film II is projected on the same side of the ball axis as the cone, (b) should be designated "minus" (−) in the formula. When the foreign body on the film II *does not* lie on the same side of the ball axis as the cone does, (b) should be designated "plus" (+) in the formula.

Substituting "opposite" direction for "same" direction in the above description, (a) or (b) becomes "plus" (+) instead of "minus" (−).

(*c*) is always "plus" (+).

Step 8—*If the distance of the foreign body as determined by the formula is "minus"* (−), *then the foreign body lies temporally. If the result is "plus"* (+), *then the foreign body lies nasally*—(with respect to the midsagittal plane of the orbit).

b. Geometric analysis of method.

Given:

Ball of the horizontal arm is located at the optic axis (intersection of horizontal and vertical planes of the eye) and designated as *R* in figure 263. The position of the cone of the localizer is represented by *P* (15 mm beneath the ball). On film I, the image of the foreign body is projected above the optic axis and hence is located cephalad. The foreign body within the eyeball is therefore located somewhere nasally or temporally along a projected line from the image of the foreign body of film I. On film II, the images of the cone, ball, and foreign body are respectively projected (due to the shift of the X-ray tube caudally).

Construct:

Horizontal line to represent plane of film position of superimposed image of ball and cone and foreign body from film I onto film plane (horizontal line).

Line perpendicular to film plane from superimposed image of ball and cone on film I.

Line parallel to perpendicular from position of foreign body from film I to represent path of incident X-ray beam through *X*.

Let:

R represent position of ball on perpendicular line.

N represent position of cone on perpendicular line (15 mm below *R*).

Construct:

Line through *R* parallel to plane of film.

Line through *N*, parallel to plane of film.

Then:

Measurements of *a*, *b*, and *c* can be determined from films I and II.

Let:

$RQ = a$
$NO = c$
$RP = b$

Construct:

RO to represent incident beam of X-ray tube shift for exposure of ball on film II.

Line through *N* parallel to *RO* for image of cone on film II.

Line through *P* parallel to *RO* for image of foreign body on film II.

Where parallel line through P intersects projected line of foreign body, from film I, is distance of foreign object in eyeball (*XQ*).

Since:

RN is parallel to *XQ* (representing incident beam from X-ray tube in film I position).

XP is parallel to *RO* (representing incident beam from X-ray tube in film II position).

And:

QP is parallel to *NO* (by construction).

Therefore:

$$\Delta RNO \sim \Delta XQP$$
$$\frac{XQ}{QP} = \frac{RN}{NO}$$
$$XQ = \frac{QP}{NO} \times RN$$

Since:

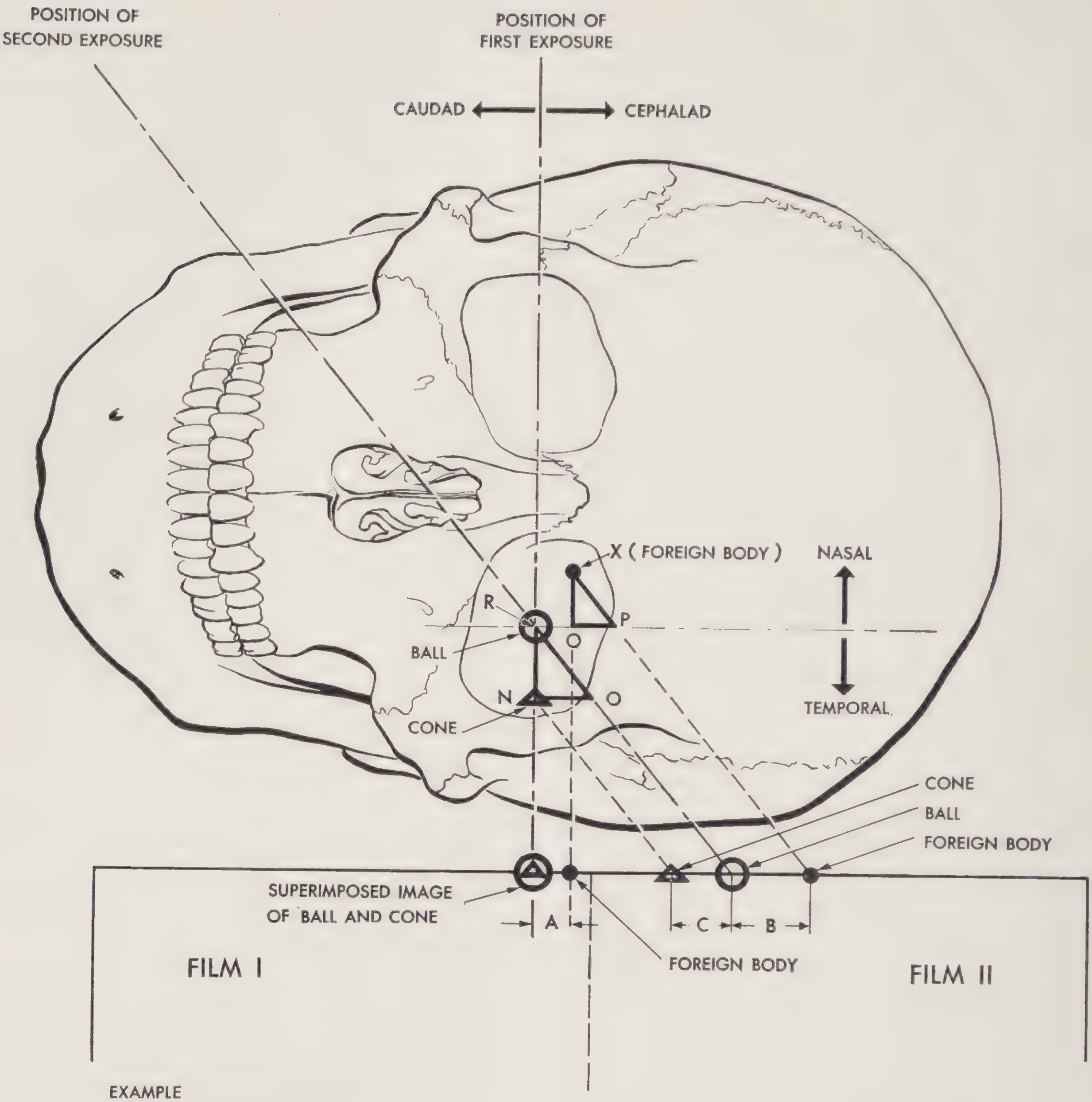
XQ = distance of foreign body (nasally) from optic axis.
$NO = c$
$RQ = a$
$RP = b$
$RN = 15$ mm

And:

$$QP = RP - RQ$$
$$= (b - a) \quad \text{or} \quad (-a + b)$$

Substituting:

$$XQ = \frac{QP}{NO} \times RN$$
$$= -\frac{a + b}{c} \times 15$$



EXAMPLE

BY MEASUREMENT ON FILM

A = –6 MM

B= +12 MM

C = 8 MM

SUBSTITUTING IN FORMULA

$$\text{DISTANCE OF FOREIGN BODY} = \frac{\pm A \pm B}{C} \times 15$$

$$= \frac{-6 + 12}{8} \times 15$$

$$= 11.25 \text{ MM}$$

SINCE ANSWER IS PLUS,
FOREIGN BODY IS
NASALLY LOCATED

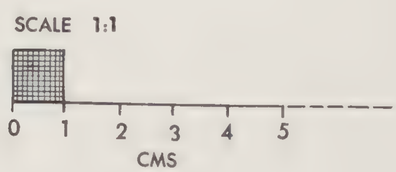


Figure 263. Geometric representation of eye localization without eye chart—Item 60510.

278. IDENTIFICATION OF INTRAOCULAR VERSUS EXTRAOCULAR POSITIONS OF FOREIGN BODY. Not infrequently, foreign bodies are found to be located in a position which raises the question as to whether they are actually contained within the eyeball or whether they might be resting in the periocular fat or even in the eyelid or the bony orbit. In such cases, it is advisable to make a two-exposure study. The headrest described above may be used and the patient may be positioned in the same manner as just described. The focal spot of the X-ray tube is aligned over the center of the orbit and the X-ray tube at a working distance such as 30 inches, and two exposures are made, using factors as described above but without shifting the tube between the two exposures; instead, merely having the patient "look up" during the first exposure and "look down" during the second exposure. If there is no duplication in the outline of the foreign body or change in configuration of it, the evidence is that it is located outside of the orbit. This is a most important revelation since it may alter the course of surgery considerably.

279. LOCALIZATION OF FOREIGN BODIES BY SINGLE FILM METHOD. a. General. The design of an X-ray table unit may not permit application of the roentgenoscopic method of localization such as described for either of the two types of field table units. When that method cannot be used or when other special procedures are not available, a simple triangulation method may be applied roentgenographically, as described below. This method is generally not to be recommended because it is less accurate than the roentgenoscopic method and furthermore, it requires more time for the actual exposure projections and calculations in addition to the time required for processing the film.

b. Procedure:

(1) Arrange the tube and roentgenoscopic screen as for ordinary horizontal roentgenoscopy. Survey the region where the foreign body is suspected. Upon identification of the foreign body, close the roentgenoscopic shutters so as to produce an effective portal on the roentgenoscopic screen measuring approximately 3 cms. square. Shift the tube and screen until the foreign body is projected into the center of this field and mark the skin surface—thereby "spotting" the foreign body.

(2) Position the X-ray tube over the table, aligning the focal spot to the spotting described above. The focal film distance may be 30, 36, or 40 inches but the exact focal film distance must be known.

(3) Position the film beneath the part and make an exposure of about three-fourths the normal exposure required for the part in question.

(4) Shift the tube a known distance (6 or 8 inches) cephalad or caudad (or transversely) and make a second exposure using the same factors as described above.

(5) Process the film in the usual manner.

(6) Carefully measure the distance between the two images of the foreign body as projected onto the film.

(7) Apply the formula: Focal-film distance *minus* foreign body film distance: tube shift: : foreign body film distance: image shift. That is: Foreign body-film

$$\text{distance} = \frac{\text{image shift X focal-film distance}}{\text{image shift} + \text{tube shift}}$$

c. Geometric explanation. See figure 264.

d. Knowing the focal-film distance, the distance of tube shift and the shift of the roentgenographic image of the foreign body (as measured on the film) it is possible to apply this method by way of graphic reproduction; actually drawing the lines represented by the triangles of the above figure and thereafter measuring the position of the foreign body with respect to the film. In order to calculate the depth of the foreign body beneath the skin spotting, it is necessary to have measured the thickness of the part through the plane of the spotting and to subtract the foreign body film distance from that value.

LET:

A = IMAGE SHIFT
B = TUBE SHIFT
D = FOCAL-FILM DISTANCE
X = FOREIGN BODY -FILM DISTANCE

SIMILAR TRIANGLES ARE CONCERNED

$$\therefore \frac{X}{A} = \frac{D-X}{B}$$

$$XB = A(D-X)$$

$$XB = AD - AX$$

$$XB + AX = AD$$

$$X(A+B) = AD$$

$$X = \frac{AD}{A+B} \quad \text{FORMULA}$$

SUPPOSE:

A = 1 INCH
B = 6 INCHES
D = 30 INCHES

TO FIND X ····

$$X = \frac{1 \times 30}{1+6} =$$

$$\frac{30}{7} = 4.29 \text{ INCHES}$$

OR

$$= 10.89 \text{ CM}$$

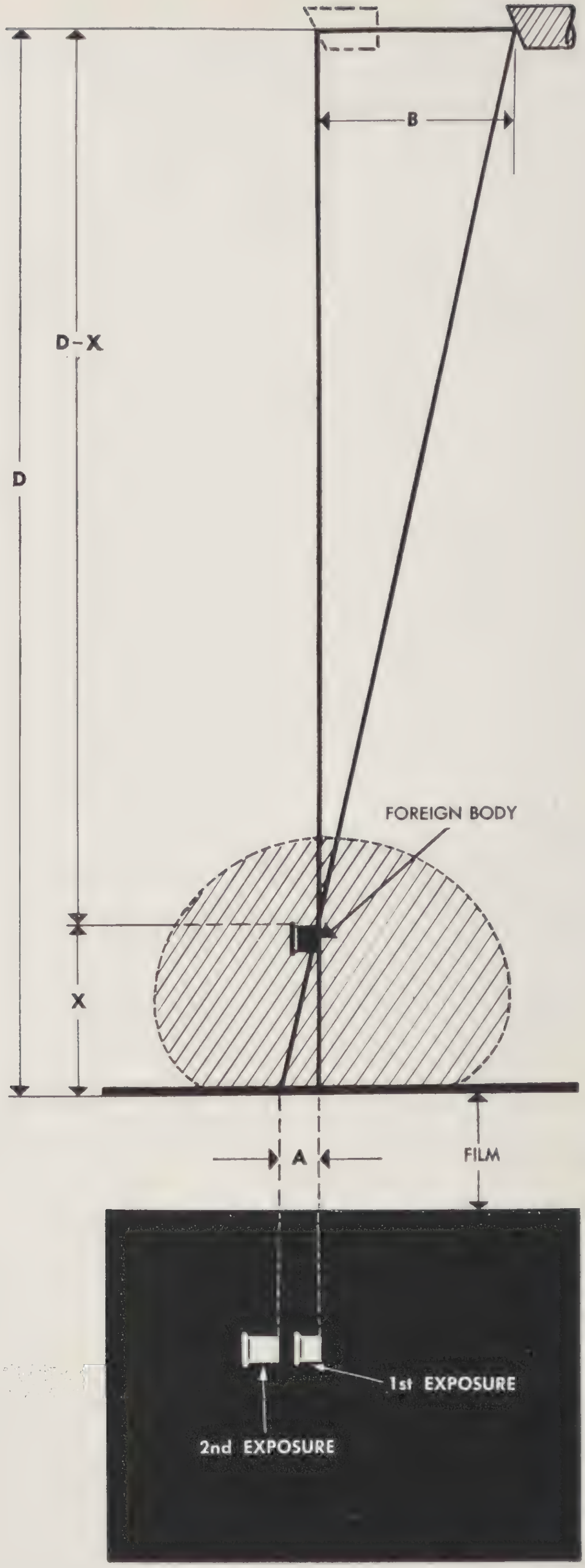


Figure 264. A simple roentgenographic method for foreign body localization.

APPENDIX I

DARKROOM DON'TS

DON'TS—RULES	WHY—REASONS	WHAT TO DO—ACTIONS
General	*General*	*General*
1. Don't use a darkroom without adequate lead protection.	Lead protects the film from fogging and the technicians from X-ray exposures.	Insist upon adequate lead protection, usually, 1.5 mm of lead.
2. Don't permit the dark room to become too hot. About 75° F.	A hot room makes the regulation of solution and temperatures difficult.	Use electric fans and outside ventilation if possible.
3. Don't guess at processing times......	Most individuals can not estimate time accurately enough for darkroom requirements.	Always use darkroom timer or clock.
4. Don't store large quantities of films..	Films deteriorate with age.............	Keep a small surplus; renew your supply frequently.
5. Don't keep boxes of films lying flat...	Static charges of electricity may collect from pressure.	Stand film boxes on end.
Cassettes and screens	*Cassettes and screens*	*Cassettes and screens*
6. Don't permit screens to become dirty.	Dirt reduces screen sensitivity, resulting in spotted films.	Wash screens monthly—use pure grain alcohol and lint-free cloth.
7. Don't load, unload, or leave cassettes near processing tanks.	Drops of liquid may be splashed on the screens, reducing their sensitivity.	Keep loading bench far away from solutions.
8. Don't leave cassettes open..........	Exposes screens to damage by dirt, liquids, and other objects.	Keep cassettes closed when not in use.
9. Don't rub or scratch screen surfaces..	Decreases screen life by destroying protective coat.	Brush screen surface lightly—use soft materials, such as camel's-hair brush.
10. Don't touch screen surfaces with your fingers.	The oil in finger prints reduces screen sensitivity.	When exchanging screens, touch only the edges.
Dry films	*Dry films*	*Dry films*
11. Don't bend, crease, press, or buckle films.	Black, half-moon marks may occur......	Handle films carefully to keep surfaces flat and smooth.
12. Don't scratch films with finger nails or other hard objects.	Scratches appear as light or dark streaks on films.	Use finger tips and not nails when handling films.
13. Don't slide or shuffle dry films over flat surface.	Films may become scratched; static electricity may develop.	When films are moved, free them from all supporting surfaces.
14. Don't leave film boxes uncovered....	Films become fogged with irregular markings.	Keep film boxes closed and in dark cabinet when not in use.
15. Don't pile films on top of one another before mounting on the hangers.	Static electricity may be developed......	When film is removed from the cassette, place it on a hanger immediately.
Chemicals and solutions	*Chemicals and solutions*	*Chemicals and solutions*
16. Don't use same paddle to stir developer and hypo.	Developer may become contaminated with hypo.	Have one paddle for developer; another for hypo.
17. Don't mix developer in vessels other than glass, stainless steel, enamel, or earthenware.	Other materials contaminate the solutions and destroy their action.	Use glass, stainless steel, enamel, or earthenware vessels for mixing solutions.
18. Don't use scouring powder to cleanse the tanks.	Scouring powder is difficult to remove. May "spot" films.	Use stiff brush and water to cleanse tanks.
19. Don't leave solutions uncovered when not in use.	They may become contaminated with dirt. Loss of water by evaporation.	Keep processing tanks covered with semi-tight lid when not in use.

DON'TS—RULES	WHY—REASONS	WHAT TO DO—ACTIONS
Chemicals and solutions	*Chemicals and solutions*	*Chemicals and solutions*
20. Don't use solutions at beginning of the day's work without stirring them.	Solid chemicals may collect on bottom of the tank. Solutions become stratified.	Develop a habit of stirring solutions when they have not been used for a few hours.
21. Don't fail to agitate films for a few seconds when placed in the solution.	Formation of air bubbles is prevented and new solution is brought to the emulsion surface.	Move films slowly up and down and back and forth without exposing any part to air.
22. Don't remove films from solution too rapidly.	Excess solution is carried away from the tank.	Use 5 seconds in removing the film. Allow 5 seconds for draining.
23. Don't permit developer to drop below the proper level.	Portions of the film surface may be exposed above the developer.	Check level frequently. Add developer to maintain proper level.
24. Don't add water to developer to maintain proper level.	Developer will become diluted and therefore slower in its action on the films.	Keep a bottle of developer nearby with which to replenish.
25. Don't ever put a film in the developer after it has been in hypo.	Hypo destroys alkalinity of the developer.	Keep well in mind the relative positions of the developer and the hypo tanks.
26. Don't crowd films in the developing tank.	Films may rub together and become stuck.	Allow at least 1 inch of space between films.
27. Don't transfer films directly from developer to hypo without rinsing in water.	Excess developer on the film surface will be carried to the hypo.	Always rinse films in water before putting them into the hypo.
Fixing	*Fixing*	*Fixing*
28. Don't allow hypo to drop below proper level.	Portions of the film may not be "fixed."	Add hypo if necessary. Keep tank covered when not in use to prevent evaporation.
29. Don't add water to hypo to maintain proper level.	Hypo becomes diluted.................	Add hypo, not water.
30. Don't attempt to clear films in exhausted hypo.	Films may become brown on aging......	Use new hypo.
Washing	*Washing*	*Washing*
31. Don't guess at washing times........	Incomplete washing may occur, or emulsion may be softened and frilled.	Fifteen minutes in water changing at rate of eight tanks per hour.
32. Don't allow wash water level to become too low.	Tops of hangers may not be cleansed. Films become streaked with hypo.	Keep entire film and hanger below surface of the wash water.
33. Don't use wash water below 50° F...	Washing time is increased at the low temperatures.	Maintain wash water temperature above 50° F.
34. Don't use wash water above 80° F...	Frilling of film emulsion may occur......	Maintain wash water temperature below 90° F.
Handling wet films	*Handling wet films*	*Handling wet films*
35. Don't lay wet films on flat surfaces...	Emulsion may stick to the surface and be removed from film base.	Make the processing procedure continuous until films are dry.
Drying	*Drying*	*Drying*
36. Don't dry films at too high temperature.	Rapid drying may result in uneven drying, with warping.	Keep dryer temperature between 75° and 90° F.; relative humidity between 15 and 40 percent.
37. Don't crowd films in the dryer.......	Films may become stuck together. Inadequate circulation of air.	If possible, leave one-half of the spaces unoccupied.

APPENDIX II

CONTRAST MEDIA

EXAMINATION	INITIAL PREPARATION	MEDIUM USED	ROENTGEN STUDIES	SUBSEQUENT CONSIDERATIONS
Gastro-intestinal tract:	....	Barium sulphate (U. S. P.).		
a. Esophagus..	No food nor fluids previous 8 hours.	Thin meal: Barium, 1 part (vol.). Water, 1 part (vol.). Thick paste: Barium, 6 parts (vol.). Water, 1 part (vol.).	Roentgenoscopy: Use drinking tube; patient (recumbent and obliquely to left or prone). Patient standing or recumbent.	Perhaps need for lavage and aspirations followed by reexamination.
b. Stomach....	Quiet tract for 24 hours—no cartharsis; neither food nor fluids for previous 8 hours.	Barium, 1 part (vol.). Water, 1 part (vol.). 8 to 16 ounces total volume during roentgenoscopic filling.	Roentgenoscopy: Preliminary swallow and study of esophageal and gastric relief; subsequent addition of volume.	Positional roentgenography (or spot films); 4- to 6-hour study; thereafter fluids and food—then 24-hour study.
c. Small intestine.	As above...............	As above (cold distilled water recommended). 4 to 8 ounces total volume.	Roentgen study every 15 minutes (4 such); then every half hour, as indicated.	
d. Obstructed cases.	Miller-Abbott or similar tube for suction drainage.	None..................	Roentgenoscopy and roentgenography: Recumbent, lateral decubitus, and upright.	May inject (thru the tube) small quantity (50 to 100 cc) thin barium.
e. Colon......	Repeated 1 percent saline enemata (warm tap water) until clear return, 2 hours prior to the examination. No solids previous 12 hours.	Tepid thin barium mixture; barium 8 ounces, water 2 quarts, acacia ½ ounce—all volumetric.	Roentgenoscopic control of filling; reexamination after evacuation; possibly air injection (under roentgenoscopic control).	Roentgenography following each phase. In cases of obstruction give mineral oil—2 ounces b.i.d. and high enemata b.i.d. until barium has been eliminated.
Gall bladder.......	Fat-free diet; high carbohydrate intake for previous day. Tetra-iodophenolphthalein (quantity in accordance with weight) with fruit juice, 14 to 16 hours prior to examination.	....	Roentgenography: 14 to 17 hours following intake of dye; again, 1 to 2 hours following fatty meal (yolks of 2 eggs and equal quantity of cream).	If excessive gas, recommend enemata or pitressin (unless contra-indicated), 8 to 15 minutes and restudy. In case of vomiting or diarrhea, recommend paregoric, 1 to 2 drams and repeat. Give double dose if single dose fails; possibly intravenous dye.
Urinary tract:				
a. K. U. B....	Repeated enemata may substitute licorice powder, 2 to 3 drams or castor oil, 1 to 2 ounces, at least 20 hours prior to study. Pitressin (8 to 15 minutes) ½ hour prior to study—in cases of flatulence.	None	Roentgenography: Recumbent, A-P, oblique and occasionally erect.	A-P and oblique films with ureteral catheters inserted (to study for calculi).

EXAMINATION	INITIAL PREPARATION	MEDIUM USED	ROENTGEN STUDIES	SUBSEQUENT CONSIDERATIONS
b. Pyelography:				
(1) Intravenous.	As above; restrict fluids for at least 6 hours.	Intravenous dye (of reputable manufacturer), following "control" roentgenography. (Preliminary skin test desirable); have adrenalin ready.	Recumbent studies: Preliminary film (control); 5 minutes, 15 minutes, 30 minutes (patient erect), and 1 hour.	Films at 60 and 90 minutes in cases with poor renal function.
(2) Retrograde	As above, no restriction of fluids.	5 to 12 percent sodium iodide or commercial dye (20 percent).	Preferably, roentgenoscopic study of filling—retract catheters sacroiliac level. Roentgenography supine with 15° Trendelenberg; horizontal and 45° Fowler, plus deep inspiration, or sitting position.	15-minute interval films following withdrawal of catheters until pelves emptied (patient in Fowler position erect).
c. Cystography	Enemata; bladder lavage (1 percent warm saline).	2 to 5 percent sodium iodide—200 to 300 cc.	Roentgenography—before and after voiding: A-P, P-A and obliques.	Possibly oxygen injection studies.
d. Urethrography	Catheterization and irrigation of bladder.	5 to 12 percent sodium iodide—injected during exposure.	Roentgenography Patient in semiFowler or true Fowler position.	
Encephalography (ventriculography).	Sodium amytol, gr. 1½ to 3, night before and morning of examination; morphine sulphate, gr. ⅙ to gr. ¼ for adults (children proportionately less); no breakfast.	Air, 120 to 140 cc (by replacement)—40 to 50 cc for ventriculography; Air must be filtered.	Stereoscopic roentgenography; P-A, A-P, and laterals—vertical and recumbent.	Ice cap to head; salicylates, codeine and caffeine as needed; fluids and food as tolerated.
Myelography......	Sodium amytol, gr. 1½ to 3, night before and morning of examination.	Oxygen (or filtered air), 50 cc or iodized oil (20 to 40 percent iodine content), 2 to 6 cc.	Roentgenography: A-P and lateral stereoscopic films made immediately after injection, if oxygen (or air) is used. Spot films (A-P and lateral) (stationary grid) if iodized oil is used.	Roentgenoscopic observations-patient in modified Trendelenberg and semiFowler positions. Needle aspiration of residual oil. 24-hour roentgenography.
Bronchography (1 lobe or single lung study at a time).	Sodium amytol, gr. 1½ to 3, night before; morphine sulphate, gr. ⅙ to ¼ with scopolamine, gr. 1/150, morning of examination. Cocaine spray (5 percent to pharynx and larynx; 10 percent to Pyriform sinuses or other topical anesthetic); intranasal tube. Have barbiturate for intravenous injection in readiness to counteract cocainism.	Iodized oil (20 to 40 percent iodine content) 10 to 20 cc.	Installation of oil under roentgenoscopic control. Film studies: P-A, obliques stereoscopic and laterals.	No food or liquids for 2 to 4 hours (until cough reflex is regained); encourage postmal drainage to remove oil.

APPENDIX III

CIRCUIT DIAGRAMS—ARMY FIELD X-RAY UNITS

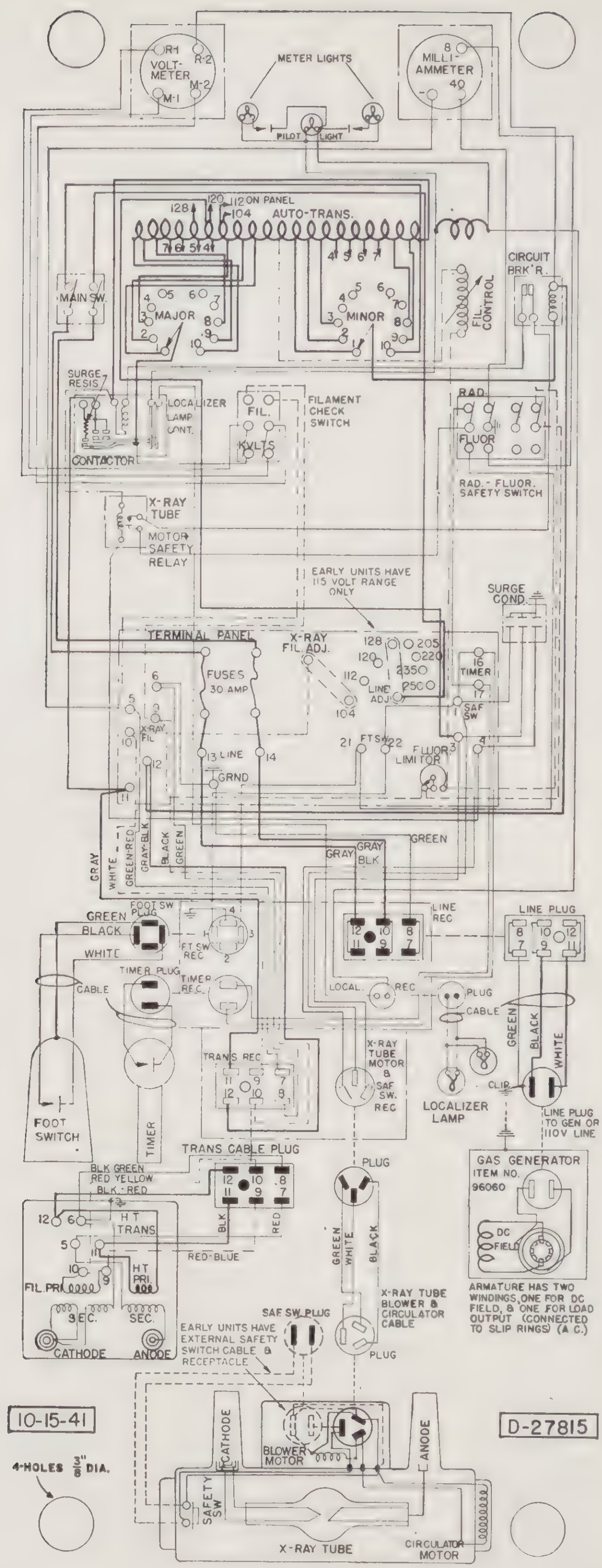


Figure A1. Circuit diagram—Army Field X-ray Unit—Item 96085.

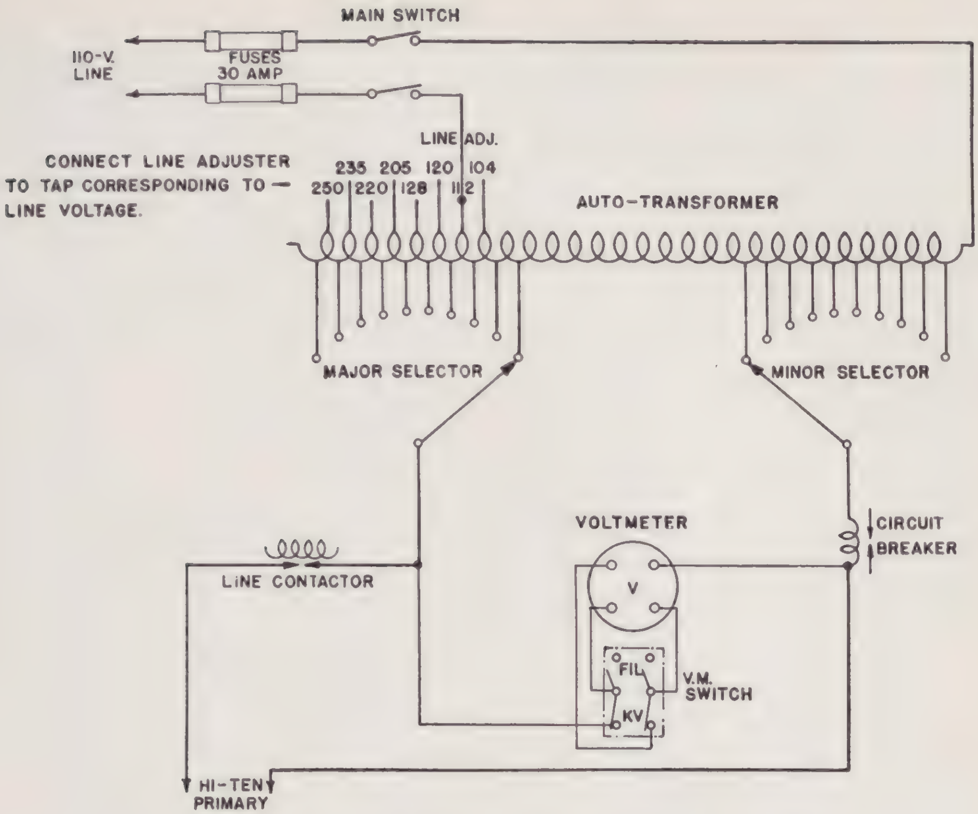


Figure A2. Primary circuit—Item No. 96085.

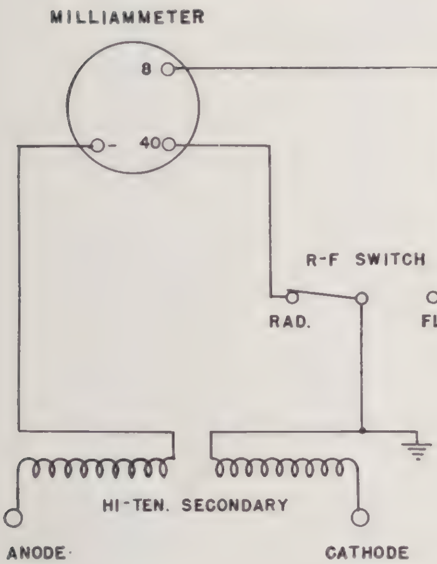


Figure A3. Milliammeter circuit —Item No. 96085.

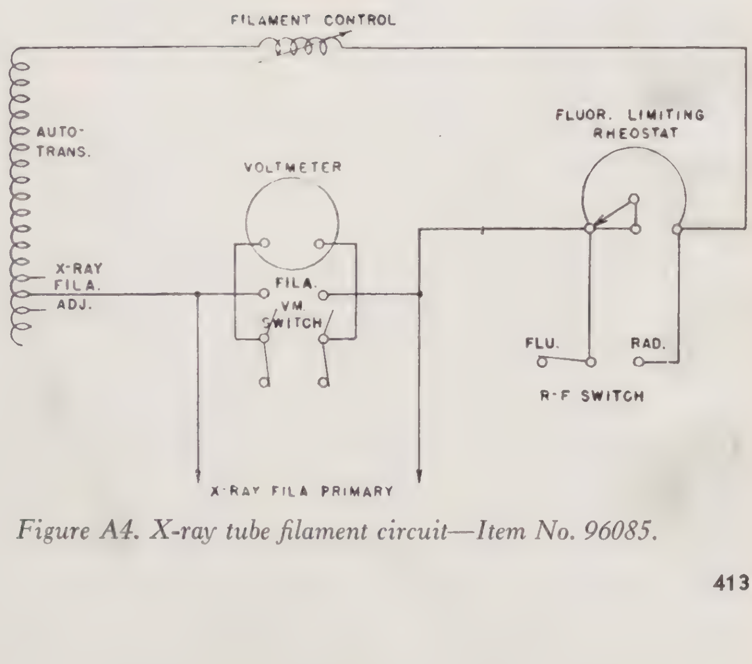


Figure A4. X-ray tube filament circuit—Item No. 96085.

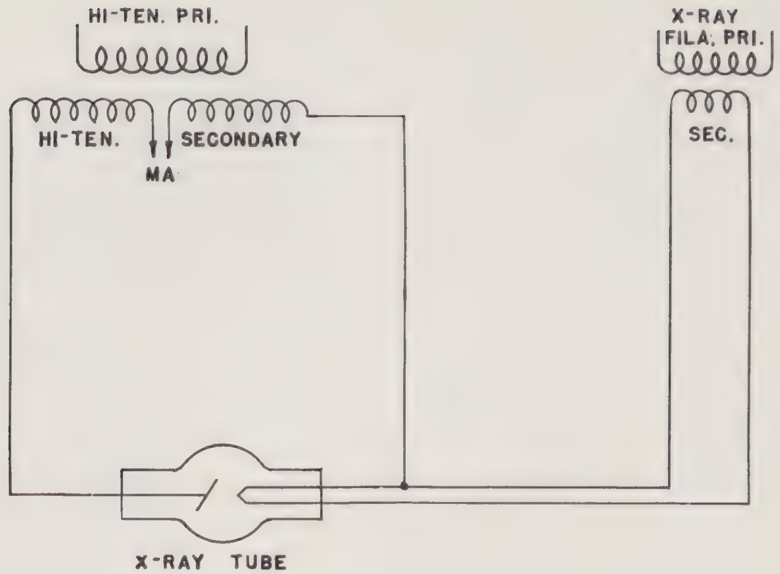


Figure A5. High tension circuit—Item No. 96085.

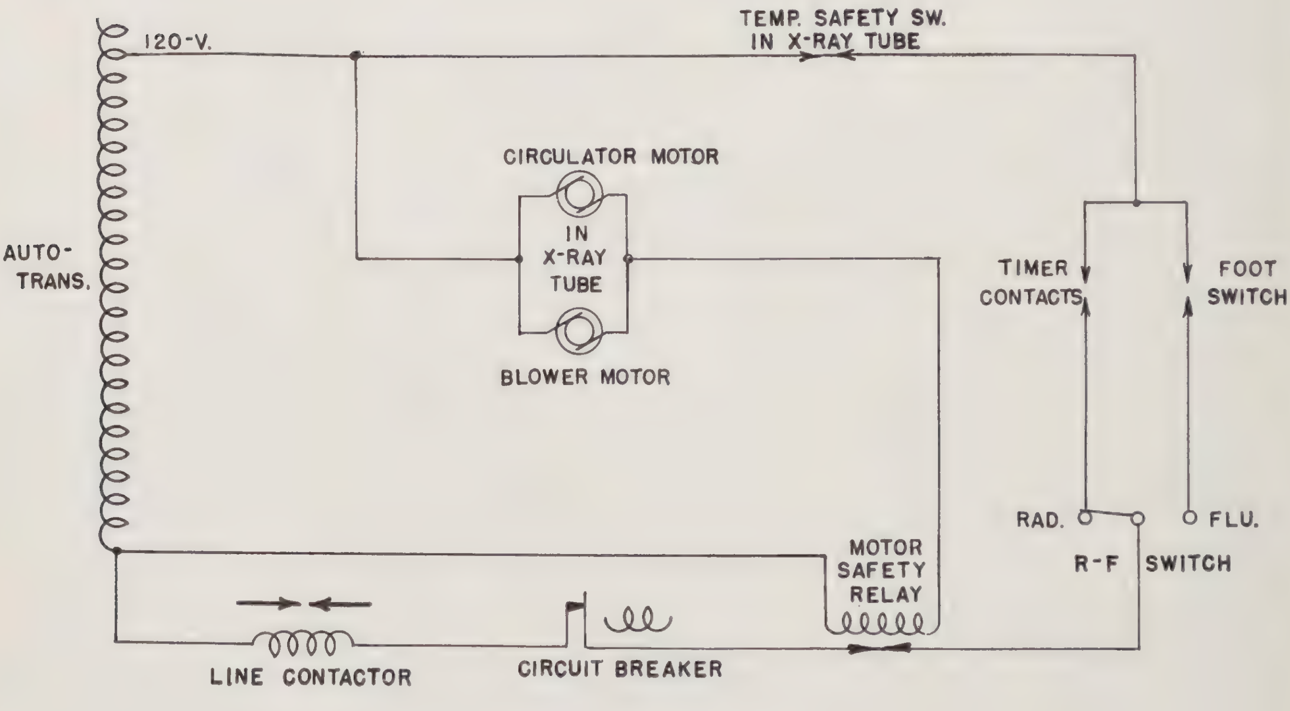


Figure A6. Operating circuit—Item No. 96085.

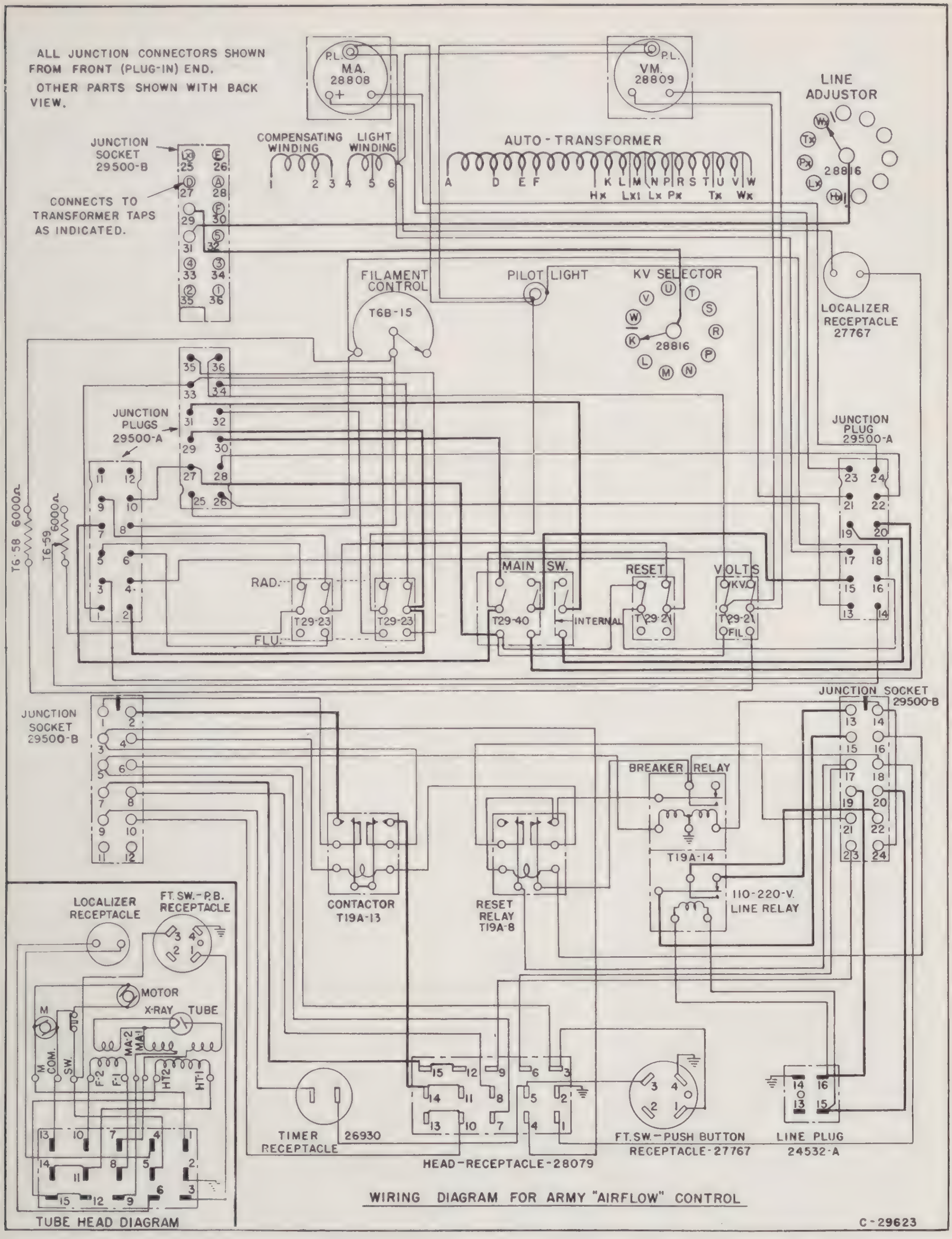


Figure A7. Circuit diagram, Army Field X-ray Unit—Item No. 96215.

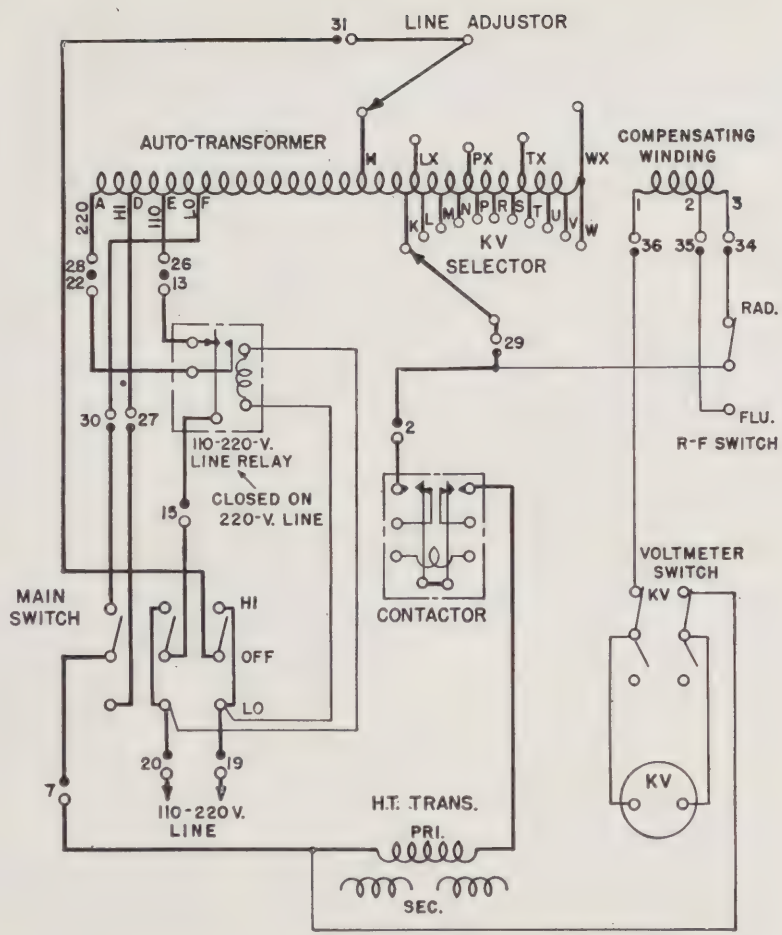


Figure A8. Autotransformer and primary circuit—Item No. 96215.

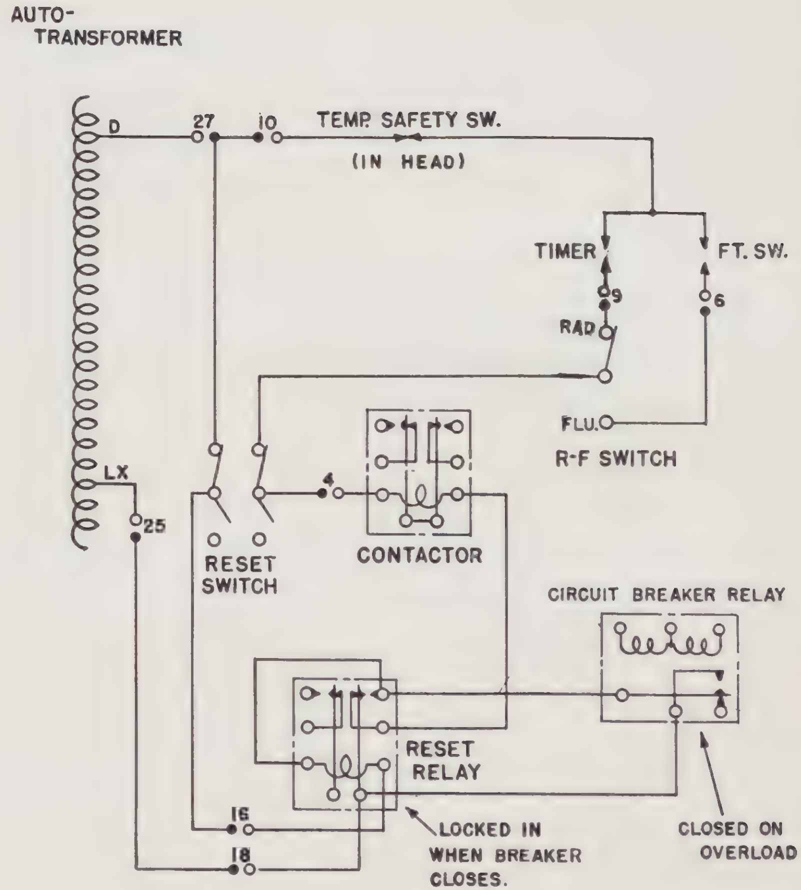


Figure A9. Contactor and control circuit—Item No. 96215.

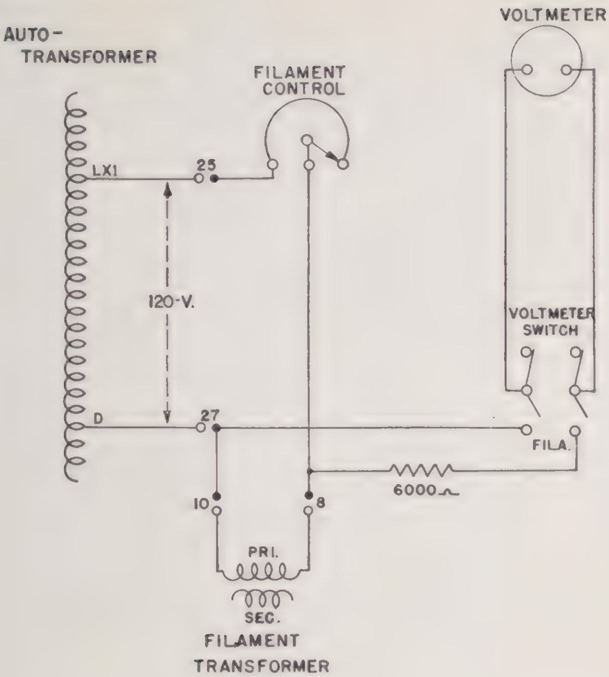


Figure A10. X-ray filament circuit—Item No. 96215.

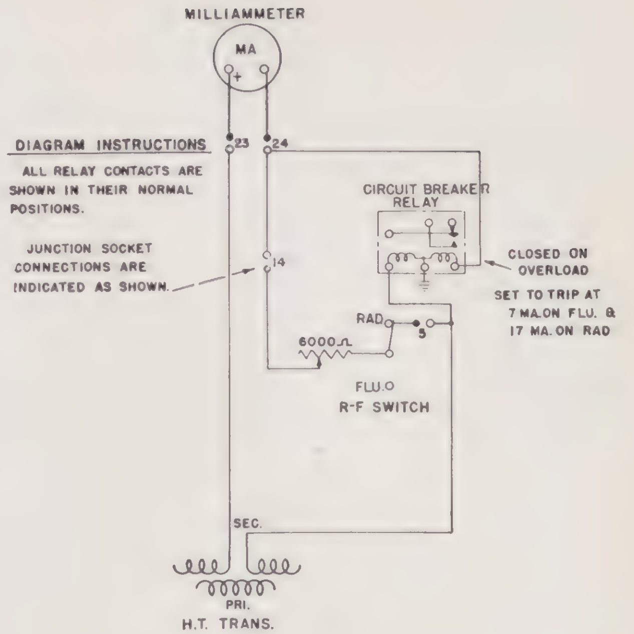


Figure A11. Milliammeter circuit—Item No. 96215.

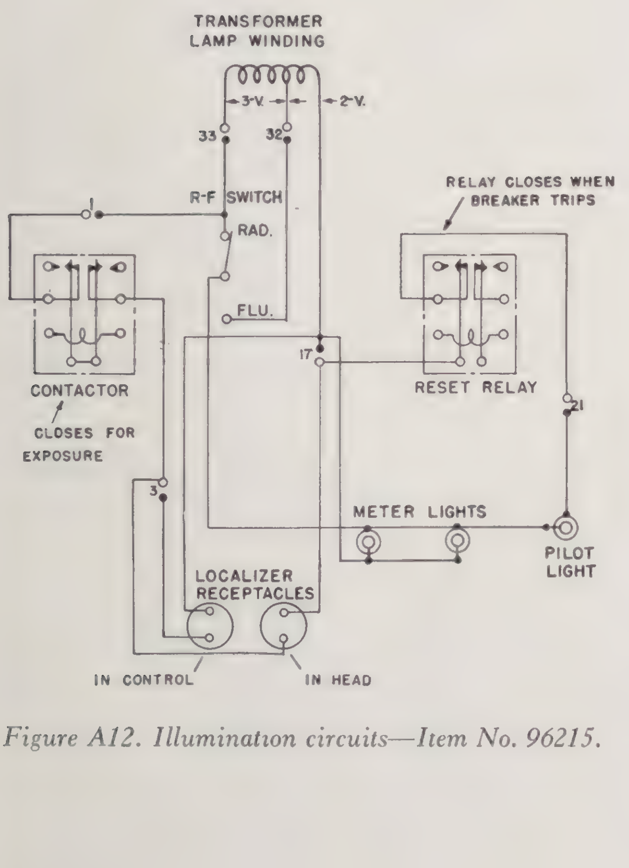


Figure A12. Illumination circuits—Item No. 96215.

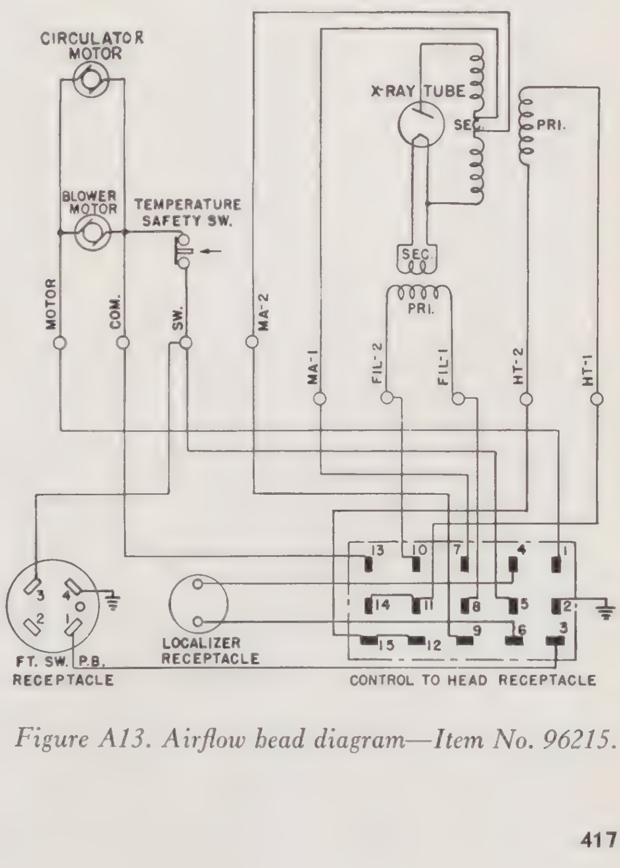


Figure A13. Airflow head diagram—Item No. 96215.

APPENDIX IV

OUTLINE OF TROUBLE ANALYSIS ESPECIALLY CONCERNING ITEM NO. 96085

Evidence	Analysis of Trouble	Possible Type of Defect	Suggested Testing Procedure for Locating Fault	Suggested Procedure for Correction of Fault
Failure of all circuits. Kvp and prereading filament meter do not indicate.	Trouble is at a point common to all circuits (from source to and including main switch and line compensator) and due to open, loose or shorted connection.	Building or line fuses—may be open; poor or defective contacts.	Visually inspect plug fuses; for cartridge fuses—use test lamp. (See Fig. 72.)	Replace with fuses of proper capacity if indicated. Clean up and tighten contacts.
		Power supply failure.	Test lamp Connect 2—110 V neon lamps in series across incoming line—if light is of normal brilliance supply is 200–250 v. If light is half of normal brilliance, supply is 100–130 V. If both segments of filament light—a-c; if only one lights—d-c.	If community power is unrepairable or unavailable use a-c gasoline—electrical generator of suitable capacity. If only d-c available use rotary converter.
		Line cable of unit including plug or receptacle.	Visually inspect plug; insert plug in wall socket and move around for contact. Use test lamp (at control end).	Clean contacts and tighten terminals. Replace line plug, receptacle or line cable if indicated.
		Control Panel Fuses.	Check for poor contact at fuse clips. Visually inspect or use test lamp—cross terminal method. (See fig. 72.)	Clean up and tighten contacts. Replace with fuses of proper capacity if indicated.
		Main switch mechanical defect, open or poor contact.	Place switch in "on" position; check for continuity—place test lamp from line adjustment terminal to ground. If no action, reverse plug in wall socket.	Tighten contacts and wire connections. Replace defective contact or entire switch if unrepairable.
		Line compensator connections.	Test electrical connections.	Tighten line adjustment terminals and connections.
Prereading filament meter shows increased reading.	Open circuit from meter through to tube filament.	Choke coil failure (96085) Rheostat failure (96215).	Connect test lamp to leads for primary of filament transformer; rotate choke coil (rheostat) through complete range—variation in brilliance of lamp indicates coil normal.	Tighten and secure all connections. Repair or replace coil (96085) or rheostat (96215) if defective.
		Failure of core to rotate. Failure of rheostat contact to rotate.	No variation in light of test lamp with rotation of filament regulator knob.	Inspect choke coil core (96085) or contact of rheostat (96215) for freedom of movement.
		Open circuit in coil or rheostat or connections therefrom.	Use test lamp; if it fails to indicate at any setting of choke coil or beyond a particular setting of rheostat (96215).	Check choke coil or rheostat for continuity. Repair or replace defective part.

Evidence	Analysis of Trouble	Possible Type of Defect	Suggested Testing Procedure for Locating Fault	Suggested Procedure for Correction of Fault
		Open, loose or shorted connection between primary of filament transformer to top of transformer tank.	Place test lamp across filament primary leads. Rotate choke coil over complete range. Variation in light indicates normal operation. No light—open circuit beyond last site of test.	Repair broken wire or connections (solder and tape). Splice broken wire ends.
		Filament transformer and cathode cable (96085).	Remove cathode cable at tubehead. *Set timer at zero, have circuit-breaker open.* Short circuit filament leads momentarily—arcing indicates filament transformer and cable normal; fault therefore is in tube or tubehead. Check concentric contacts of cathode cable. Note if spacing between contacts is uniform.	Reinsert cable to insure good contact. Test filament circuit again. If still open new tubehead is indicated. Adjust concentric contacts to insure correct spacing. Clean contacts of any foreign material.
			If no arcing occurs when leads are shorted, test indicates open circuit between end of cable and filament primary. Remove cable from transformer receptacle—insert metal clamp rod and short circuit filament terminals at transformer. If arcing occurs failure is in cable.	Switch cables; repeat testings and if defect is thereby established in one cable, repair or replace it.
			If no arcing occurs open circuit is within transformer housing.	Remove top of transformer tank—check terminal connections. Repair defect in leads or fault at terminal connections.
Prereading filament meter shows decreased reading.	Short circuit from meter connections through to tube filament.	Tubehead.	Remove cathode cable from tubehead. Check prereading meter. If increased reading—short circuit is in the tubehead.	Clean out cathode receptacle with carbon tetrachloride. Check for foreign material in receptacle or at terminals of cable. If this fails to correct fault—new tubehead required.
		Cable.	If meter still shows decreased reading, remove cable from transformer receptacle. If meter now shows an increased reading, then short circuit is in cable.	Switch cables.
		Filament Transformer.	If meter still shows a decreased reading—remove filament leads on top of transformer tank. If meter continues to show an increased reading then short is within transformer tank.	Remove top of transformer tank. Inspect terminal. Check insulation of binding post—repair such.
		Leads to primary of filament transformer.	Remove filament primary wires from panel. If meter reading is still high, then short is between this point and meter connections.	Remove control housing and inspect wiring from panel to meter; tighten connections—provide insulation.
			If meter shows a decreased reading, short is between this point and top of transformer.	Repair wiring, especially at plug. (Check from plug to terminals on transformer.)

Evidence	Analysis of Trouble	Possible Type of Defect	Suggested Testing Procedure for Locating Fault	Suggested Procedure for Correction of Fault
Tubehead motors (air blower and oil impeller) do not operate.	Open circuit in one or both motors.	Motor safety relay.	Use test lamp 60 to 100 watts. Place lamp leads across motor terminals on panel. If lamp lights, motor safety relay is normal; if not, motor safety relay or wiring thereto is open circuited.	Remove relay; connect coil leads together to energize motor or replace with new relay.
	Open circuit in wiring or open circuit in motor safety coil.	Motors themselves or their wiring connections.	If lamp lights in above test, place test lamp leads across motor leads in plug at tube housing; if lamp lights, then failure is in tube housing.	Remove blower unit—inspect wiring to motor.
		Motors.	Connect 110 V. across each motor in turn; if no operation, then motor is open-circuited.	Short-out either or both motors (may be 60 to 100 watt lamp across motor terminals on panel board)—limit exposures to approximately ⅕ normal, or replace motors.
		Cable from control to tube housing.	If test lamp fails to light at end of motor cable, then failure is in cable.	Replace cable or make up new cable (having 3 leads)
Contactor does not close.	No audible closing of contactor.	There are five separate parts in this circuit; eliminate in order. (1) Hand timer.	Bypass by short-circuiting timer receptacle at rear of control.	Open case, check mechanism contacts and wiring for defects. Check male plug for loose or broken wire.
		(2) Thermal safety switch.	Bond thermal safety binding posts on control panel. Determine if contactor now functions.	Make bond permanent. Obtain replacement of contacts.
		(3) Radiographic-fluoroscopic switch.	Check switch action. Test its operation on both sides for both on radiography or fluoroscopy.	Remove switch and check contacts, clean and adjust contacts, replace switch if necessary.
		(4) Circuit-breaker contacts.	Manually check tension (should permit complete and easy resetting; should open with load above 30 ma —85 kvp).	Bend contact blades to assure definite electrical contact.
		(5) Motor relay contacts.	Remove kvp meter and feel for definite closing.	Remove control panel cover, adjust tension or distance of contacts.
		(6) Main contactor.	Expose contacts—note any evidence of pitting or inequality of spacings (surge resistor contacts should have spacing of ¼ inch; armature of main contactor ⅜ inch; main contactor 1 5/32 inch).	Adjust contacts accordingly.
Milliammeter meter fails to register.	Do not assume that X-rays are not being produced.	Milliammeter circuit.	Place fluoroscopic screen in front of exit portal. If fluorescence occurs X-rays are produced and meter must be bypassed. Check binding posts on top of transformer housing and at control panel.	Clear wiring of short circuit or ground from top of transformer to milliammeter connections.

Evidence	Analysis of Trouble	Possible Type of Defect	Suggested Testing Procedure for Locating Fault	Suggested Procedure for Correction of Fault
	Primary of high tension not energized.	Primary circuit from contactor to top of transformer.	Place test lamp across terminals of high tension primary on top of transformer. Energize in normal manner if no light, failure is between this point and contactor.	Replace broken wire with auxiliary lead. Replace control transformer cable.
	Open milliammeter circuit (transformer-meter).	Wiring from midpoint of high tension transformer to control panel.	Bond milliammeter terminals on top of transformer tank; if X-rays are produced, then the circuit is open from that point to meter.	Examine wiring for open circuit and replace with auxiliary wire. Replace control transformer cable. Check binding posts on back of meter.
	Open circuit secondary high tension transformer.	High tension transformer or cables.	Place high tension terminals 1 to $1\frac{1}{2}''$ apart on dry wood. Adjust autotransformer setting to about 40 kvp; *ground unit;* make exposure; if arcing occurs, failure is in tube or tubehead. If no spark over occurs between cable ends, then place one cable 1 inch from ground; make exposure. If arcing over occurs, then half of secondary is normal and primary winding is normal.	Replace tubehead as a unit.
			Place end of other cable 1 inch from ground, make exposure as before; if no arcing, then open circuit is in that half of secondary.	Remove transformer from housing. Inspect for carbonization of winding. Winding will undoubtedly be burned; remove up to 5 turns on secondary, splice and tie in close to winding. Limit operation to maximum of 80 kvp. Replace transformer oil.
Milliammeter fluctuates.	Insulation failure of High Tension cable or transformer oil.	Cable.	Watch for breakdown to ground (manifested in arcing or cracking sound). DO NOT GET WITHIN 12 INCHES OF CABLE.	Repair cable or replace if necessary.
		Transformer oil.	Listen for cracking sound within transformer case, look for seepage of smoke from case. Note any odor of carbonization.	Remove transformer from case. Replace or repair charred wire. Replace transformer oil. Insure proper clearance between transformer and case.
	Gassy tube.	Tubehead.	Detach High Tension cables, from tubehead; set them about 10 inches apart on wood; energize unit. If meter does not indicate, then failure is in tube or tubehead.	Replace tubehead and tube.

APPENDIX V

TABLES

Table I

CORPUSCULAR RAYS			
NAME	SYMBOL	ELECTRIC CHARGE	MASS
PROTON	⊕	ONE POSITIVE	1.66×10^{-24} GRAM
ELECTRON (CATHODE RAYS)	⊖	ONE NEGATIVE	9×10^{-28} GRAM *
NEUTRON	○	ZERO	1.66×10^{-24} GRAM
ALPHA-PARTICLES (RADIOACTIVE SUBSTANCES)	⊕ ○ ○ ⊕	TWO POSITIVE	6.59×10^{-24} GRAM

* 9×10^{-28} = 9X.0000000000000000000000000001

Table II
PRINCIPAL PROPERTIES OF ROENTGEN RAYS

MOVE IN STRAIGHT LINES	NOT REGULARLY REFLECTED FROM SMOOTH SURFACES
MOVE WITH THE VELOCITY OF LIGHT	CANNOT BE SEEN OR FELT
PASS THROUGH OPAQUE SUBSTANCES	HAVE NEITHER MASS NOR ELECTRIC CHARGE
AFFECT SENSITIVE EMULSION OF PHOTOGRAPHIC FILM	PRODUCE FLUORESCENCE AND PHOSPHORESCENCE IN SOME SUBSTANCES
IONIZE GASES	DAMAGE, KILL OR STIMULATE LIVING TISSUE
DIFFERENTIALLY ABSORBED BY MATTER	LIBERATE PHOTOELECTRONS AND RECOILELECTRONS

Table III
COMMON UNITS AND TERMINOLOGY

TERM OR QUANTITY	SYMBOL	UNIT	ABBREVIATION
CURRENT, DIRECT	I, i	AMPERE, MILLIAMPERE	amp, ma, d-c
CURRENT, ALTERNATING	I, i	AMPERE, MILLIAMPERE	amp, ma, a-c
ELECTROMOTIVE FORCE	E, e	VOLT, KILOVOLT	emf, kv
POTENTIAL DIFFERENCE		VOLT, KILOVOLT	SPELL OUT
PEAK-KILOVOLT	Em	KILOVOLT	kvp*
EFFECTIVE VOLTAGE ROOT MEAN SQUARE	E	VOLT	SPELL OUT
POWER (ELECTRICAL)	P, p	WATT, KILOWATT	w, kw
POWER (MECHANICAL)		HORSEPOWER	hp
FREQUENCY (CURRENT)	f	CYCLES PER SEC.	SPELL OUT
FREQUENCY (RADIATION)	ν	CYCLES PER SEC.	SPELL OUT
QUANTITY OF ELECTRICITY	Q, q	COULOMB MILLIAMPERE-SEC.	ma-sec**
VELOCITY OF LIGHT	c	CENTIMETERS PER SECOND	cm/sec
WAVE LENGTH	λ	ANGSTROM	A
X-RAY QUANTITY	r	ROENTGEN	r unit

Additional units and symbols

RESISTANCE	R, r	OHM	SPELL OUT
CAPACITY	C	FARAD	SPELL OUT
INDUCTANCE, SELF	L	HENRY	h
INDUCTANCE, MUTUAL	M, L_1, L_2	HENRY	h
MAGNETIC FIELD STRENGTH	H	GAUSS	gs
IMPEDANCE	Z, z	OHM	SPELL OUT
REACTANCE	X, x	OHM	SPELL OUT
PHASE ANGLE	θ	RADIAN	SPELL OUT
KILOVOLT-AMPERE		KILOWATT	kva
ANGULAR VELOCITY	ω	REVOLUTIONS PER MINUTE	rpm
ILLUMINATION	E	LUX	SPELL OUT

*KVP or PKV are commonly used. **MAS is commonly used.

Table IV
RESISTIVITY (22° C.) OHMS PER CM.

CONDUCTORS		INSULATORS	
ALUMINUM	2.8×10^{-6}	RED FIBRE	5×10^{9}
BRASS (0° C.)	7×10^{-6}	GLASS	2×10^{13}
COPPER	1.7×10^{-6}	BAKELITE	5×10^{10}
PLATINUM	$10. \times 10^{-6}$	RUBBER	1×10^{18}
TUNGSTEN	5.5×10^{-6}	PORCELAIN	3×10^{14}
LEAD	22×10^{-6}	TRANSFORMER OIL	2×10^{16}

Table V

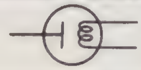
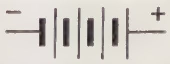
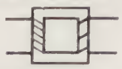
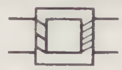
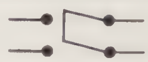
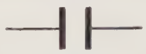
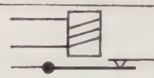
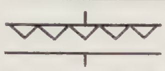
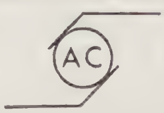
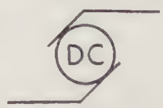
COMMON DIAGRAMMATIC SYMBOLS			
X-RAY TUBE		VALVE TUBE	
AMMETER		MILLIAMMETER	
VOLTMETER		KILOVOLTMETER	
CONNECTED WIRES		UNCONNECTED WIRES	
BATTERY		GROUND	
FIXED RESISTOR		VARIABLE RESISTOR	
STEP UP TRANSFORMER		STEP DOWN TRANSFORMER	
SINGLE POLE SWITCH		DOUBLE POLE SWITCH	
FUSE		PUSH BUTTON SWITCH	
FIXED CONDENSER		VARIABLE CONDENSER	
FIXED INDUCTOR		VARIABLE INDUCTOR	
RELAY (CIRCUIT OPEN)		RELAY (CIRCUIT CLOSED)	
INVERSE SUPPRESSOR		SPHERE GAP	
ALTERNATING CURRENT GENERATOR		DIRECT CURRENT GENERATOR	

Table VI
ROENTGEN RAY MACHINE. PRINCIPAL CIRCUITS AND INSTRUMENTS

LOW VOLTAGE SIDE	HIGH VOLTAGE SIDE (When x-ray switch is closed)
TUBE FILAMENT CONTROL CIRCUIT	
FILAMENT SWITCH (MAY BE CONNECTED TO MAIN LINE SWITCH)	FILAMENT TRANSFORMER—SECONDARY COIL
FILAMENT REGULATOR (VARIABLE RESISTOR OR CHOKE COIL)	FILAMENT AMMETER (NOT USED IN SHOCK-PROOF MACHINES)
FILAMENT METER (PRE-READING AMMETER OR VOLTMETER)	FILAMENT OF THE X-RAY TUBE (CATHODE)
FILAMENT TRANSFORMER—PRIMARY COIL	
TUBE VOLTAGE CONTROL CIRCUIT	
MAIN LINE SWITCH (MAY BE CIRCUIT BREAKER SWITCH, ALSO)	HIGH VOLTAGE TRANSFORMER-SECONDARY COIL
MAIN LINE VOLTMETER OR COMPENSATOR METER	MILLIAMMETER (NON-SHOCK PROOF MACHINES)
AUTOTRANSFORMER (MAJOR AND MINOR CONTROLS)	RECTIFIERS (VALVE-TUBE OR MECHANICAL)
PEAK KILOVOLT METER	X-RAY TUBE
HIGH VOLTAGE TRANSFORMER—PRIMARY COIL	
MILLIAMMETER (SHOCK-PROOF MACHINES)	
TIMING CIRCUIT	
X-RAY SWITCH (HAND SWITCH, FOOT SWITCH, CLOCK TIMER, SYNCHRONOUS TIMER, IMPULSE TIMER OR BUCKY SWITCH)	
CONTACTOR SWITCH	
AUXILIARY PARTS AND CIRCUITS	
CIRCUIT BREAKER (THERMAL MAGNETIC)	FILAMENT TRANSFORMERS OF VALVE-TUBES SECONDARY COILS
FUSES	FILAMENT STABILIZERS (USUALLY IN LOW VOLTAGE SIDE)
PILOT LIGHTS	
FILAMENT REGULATOR OF VALVE-TUBES	
FILAMENT METER OF VALVE-TUBES	
FILAMENT TRANSFORMER OF VALVE-TUBE —PRIMARY COIL	
SYNCHRONOUS MOTOR—MECHANICAL RECTIFIER	
POLARITY METER—MECHANICAL RECTIFIER	
TIMER RELAYS	
THERMOSTATS	
OIL, WATER AND AIR CIRCULATING DEVICES	

Table VII
POWER SUPPLY REQUIREMENTS

TYPE OF CIRCUIT	SELF-RECTIFIED			FULL-WAVE			THREE PHASE	
MACHINE CAPACITY (MILLIAMPERES)	10	30	100	200	500	1,000	500	1,000
PEAK KILOVOLTAGE	85	85	85	85	85	85	85	85
NOMINAL LINE VOLTAGE	100–130	100–130	208–240	208–240	208–240	208–240	208–240	208–240
TRANSFORMER LOAD KVA	1.5	5.0	15.0	15.0	25.0	50.0	3–15	3–25
WIRE SIZE (B. & S.) TRANSFORMER TO SWITCH*	8	6	4	4	00	300,000 cir mils	3	00
WIRE SIZE (B. & S.) SWITCH TO CONTROL‡	....	....	6	6	3	0	4	3
GROUND WIRE	8	8	8	8	6	4	8	6
FUSE CAPACITY (AMPERES)	15	40	70	70	180	350	100	200
LINE SWITCH CAPACITY (AMPERES)	BASE RECEPTACLE	60	100	100	200	400	200	200

NOTES

1. The above specifications are the minimum requirements for a single x-ray machine of the rating specified.
2. They are based on a normal line regulation of 2 percent when the x-ray machine is not in operation.

*3. Wire size based on run of 100 feet. If 200 feet double wire size.

‡4. Wire size based on a maximum run of 10 feet.

5. If more than one x-ray machine is to be used, or additional load is contemplated for the future, larger wire and transformer sizes must be specified for satisfactory operation.

Table VIII

PRINCIPAL EFFECTS OF ROENTGEN RAYS WHICH ARE USED AS QUANTITATIVE MEASURE OF X-RADIATIONS

PHYSICAL EFFECTS	CHEMICAL EFFECTS	BIOLOGICAL EFFECTS
IONIZATION OF GASES	FADING OF DYES	ERYTHEMA OF HUMAN SKIN
EXCITATION OF FLUORESCENCE	OXIDATION OF FERROUS SULPHATE	RETARDATION OF GROWTH OF SEEDLINGS
PHOTOGRAPHIC ACTIVATION OF FILM	INACTIVATION OF VITAMINS	STERILIZATION OF INSECT EGGS

Table IX

X-RADIATION EXPOSURES WITH FIELD X-RAY UNITS (ITEM 96085)

INTENSITY OF RADIATION OF FIELD X-RAY UNITS (AVERAGE OF FOUR UNITS)

85 KVP 30MA 30 inches FILM-TARGET DISTANCE		
FILTER	ROENTGENS PER MIN.	ROENTGENS PER SEC. PER MILLIAMPERE
0.24 MM, INHERENT	44	.024
0.50 MM, TOTAL	37.5	.021
1.00 MM, TOTAL	26.7	.015

MAXIMUM PERMISSIBLE EXPOSURE VALUES IN MILLIAMPERE SECONDS*

SKIN—TARGET DISTANCE (IN.)	FILTER .24 MM, INHERENT	FILTER 0.50 MM, TOTAL	FILTER 1.00 MM, TOTAL
12	335	373	533
18	750	839	1200
24	1333	1493	2133
30	2083	2333	3333
36	3000	3359	4799
60	8332	9332	13332

*This table is based on a safe total exposure of 50 roentgens in one series and over one area, or approximately 25 percent of a threshold skin erythema unit of dose (85 KVP and 1 MM AL).

Table X
FOCAL-FILM DISTANCE CONVERSION TABLE

DISTANCE DESIRED (INCHES)

KNOWN DISTANCE (INCHES)	25	30	35	40	45	48	50	55	60	65	70	72
25	1	1.44	1.96	2.56	3.56	3.68	4	4.84	5.76	6.76	7.84	8.29
30	.69	1	1.36	1.77	2.24	2.56	2.78	3.36	4	4.70	5.44	5.73
35	.59	.74	1	1.31	1.65	1.88	2.04	2.47	2.94	3.45	4	4.23
40	.39	.56	.77	1	1.28	1.44	1.57	1.90	2.25	2.64	3.06	3.24
45	.31	.44	.61	.79	1	1.14	1.23	1.49	1.77	2.08	2.42	2.56
48	.27	.39	.53	.69	.88	1	1.08	1.31	1.56	1.83	2.13	2.25
50	.25	.36	.49	.64	.81	.92	1	1.29	1.44	1.69	1.96	2.07
55	.21	.30	.40	.53	.67	.76	.83	1	1.19	1.31	1.62	1.72
60	.17	.25	.34	.44	.56	.64	.69	.84	1	1.17	1.39	1.44
65	.15	.21	.29	.38	.48	.55	.59	.71	.85	1	1.15	1.23
70	.13	.18	.25	.33	.41	.47	.51	.62	.73	.88	1	1.06
72	.12	.17	.24	.31	.39	.44	.48	.58	.69	.81	.95	1

MULTIPLYING FACTORS

Table XI
KILOVOLTAGE MILLIAMPERE—SECOND RELATIONSHIP

WHEN DECREASING exposure (time, ma., or ma.s) increase kvp as follows:

ORIGINAL KVP	ADJUSTED VALUES OF KVP FOR DECREASING ORIGINAL EXPOSURE TIME TO 3/4	1/2	1/4
30	32	36	42
40	42	48	56
50	53	60	70
60	64	72	84
70	75	84	
80	86		

WHEN INCREASING exposure (time, ma., or ma.s) decrease kvp as follows:

ORIGINAL KVP	INCREASE ORIGINAL EXPOSURE TIME TO 1 1/4	1 1/2	1 3/4	2
40	38	36	34	33
50	48	45	43	42
60	57	54	52	50
70	66	63	61	59
80	76	72	69	67
90	85	81	78	76

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